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Gulf Coast Salt Domes
Geologic Area Characterization Report
East Texas Study Area

Volume II
Technical Report

July 1982

Law Engineering Testing Company
2749 Delk Road, S.E.
Marietta, GA 30067

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Office of Nuclear Waste Isolation

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ABSTRACT

The East Texas Area Characterization Report (ACR) is a compilation of data gathered during the Area Characterization phase of the Department of Energy's National Waste Terminal Storage program in salt.

The characterization of Gulf Coast Salt Domes as a potential site for storge of nuclear waste is an ongoing process. This report summarizes investigations covering an area of approximately 2,590 km^2 (1,000 mi^2). Subsequent phases of the program will focus on smaller land areas and fewer specific salt domes, with progressively more detailed investigations, possibly culminating with a license application to the Nuclear Regulatory Commission.

The data in this report are a result of drilling and sampling, geophysical and geologic field work, and intensive literature review. The ACR contains text discussing data usage, interpretations, results and conclusions based on available geologic and hydrologic data, and figures including diagrams showing data point locations, geologic and hydrologic maps, geologic cross sections, and other geologic and hydrologic information. An appendix contains raw data gathered during this phase of the project and used in the preparation of these reports.

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IV

VOLUME II
TABLE OF CONTENTS

Page

ABSTRACT iii

LIST OF TABLES vii

LIST OF FIGURES ix

GLOSSARY OF GEOLOGICAL TERMS xv

CONVERSION FACTORS xxxv

ABBREVIATIONS AND ACRONYMS xxxvi

6 GEOLOGIC CHARACTERIZATION OF EAST TEXAS BASIN STUDY AREA 6-1

6.1 DESCRIPTION OF THE EAST TEXAS STUDY AREA 6-1

6.2 GEOLOGY OF THE EAST TEXAS STUDY AREA 6-7

6.2.1 Physiography and Geomorphology 6-7
6.2.2 Stratigraphy 6-21
6.2.3 Structure 6-55
6.2.4 Geological History 6-77
6.2.5 East Texas Area Seismicity 6-80

6.3 MINERAL RESOURCES OF THE EAST TEXAS STUDY AREA 6-106

6.3.1 Hydrocarbon Resources 6-106
6.3.2 Lignite 6-116
6.3.3 Salt 6-117
6.3.4 Stone 6-118
6.3.5 Other Resources 6-118

6.4 SUMMARY OF THE EAST TEXAS STUDY AREA 6-118

6.5 LIST OF REFERENCES CITED 6-122

7.0 GEOLOGIC CHARACTERIZATION OF SELECTED DOMES IN THE EAST TEXAS BASIN STUDY AREA 7-1

7.1 OAKWOOD DOME 7-2

7.1.1 DOME GEOMETRY AND COMPOSITION 7-3
7.1.2 NEAR-DOME GEOLOGY 7-21
7.1.3 MINERAL RESOURCES 7-43

7.2 KEECHI DOME 7-46

7.2.1 Dome Geometry and Composition 7-46
7.2.2 Near-Dome Geology 7-54
7.2.3 Mineral Resources 7-79

VOLUME II
TABLE OF CONTENTS (Continued)

Page

7.3 PALESTINE DOME 7-83

7.3.1 Dome Geometry and Composition 7-83
7.3.2 Near-Dome Geology 7-90
7.3.3 Mineral Resources 7-112

7.4 SUMMARY OF SELECTED DOMES 7-115

7.5 LIST OF REFERENCES CITED 7-118

8.0 HYDROLOGIC CHARACTERIZATION OF THE EAST TEXAS STUDY AREA 8-1

8.1 HYDROLOGIC FIELD DATA-COLLECTION PROGRAM, EAST TEXAS STUDY AREA 8-2

8.1.1 Surface Water 8-5
8.1.2 Ground Water 8-5
8.1.3 Water Chemistry 8-6

8.2 HYDROLOGIC CHARACTERIZATION OF THE EAST TEXAS STUDY AREA 8-6

8.2.1 Regional Surface-Water Hydrology 8-9
8.2.2 Regional Ground-Water Hydrology 8-11
8.2.3 Water Chemistry 8-24
8.2.4 Relationship of Surface Water to Ground Water 8-31
8.2.5 Water and Aquifer Use 8-31

8.3 HYDROLOGIC CHARACTERIZATION OF SELECTED SALT DOMES IN THE EAST TEXAS STUDY AREA 8-37

8.3.1 Palestine Salt Dome 8-37
8.3.2 Oakwood Salt Dome 8-38
8.3.3 Keechi Salt Dome 8-56

8.4 SUMMARY OF HYDROLOGIC CHARACTERIZATION OF THE EAST TEXAS STUDY AREA 8-67

8.5 LIST OF REFERENCES CITED 8-70

REVIEW COMMENTS TO DRAFT REPORT WITH REPLIES

VOLUME II
LIST OF TABLES

Table No. Title Page

Chapter 6

6-1 East Texas Study Area Summary of Stratigraphy 6-23

6-2 Study Area Oil and Gas Field Summary 6-112

Chapter 7

7-1 Oakwood Dome Borehole Data Summary 7-4

7-2 Keechi Dome Borehole Data Summary 7-55

7-3 Palestine Dome Borehole Data Summary 7-89

Chapter 8

8-1 Generalized Stratigraphy and Water-Bearing Characteristics of Geologic Units in the East Texas Study Area 8-16

8-2 Summary of Water Use in the East Texas Study Area 8-33

8-3 Summary of Aquifer System Properties Determined from Data Collection Sites 8-48

8-4 Selected Chemical Analyses of Ground Water From Geologic and Hydrologic Test Sites 8-55

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VOLUME II
LIST OF FIGURES

Figure No.	Title	Page
	Chapter 6	
6-1	Location Map	6-3
6-2	Topographic Map	6-5
6-3	Location of Wells and Seismic Reflection Lines	6-9
6-4	Landsat and Low-level Imagery Coverage	6-11
6-5	Major Drainage Network	6-13
6-6	Physiographic Features Map	6-17
6-7	Geologic Map	6-19
6-8	Composite Geophysical Well Log	6-25
6-9	Salt Masses and Major Salt Anticlinal Trends	6-33
6-10	Cross Section A-A' Based on Seismic and Well Data	6-35
6-11	Cross Section B-B' Based on Seismic and Well Data	6-39
6-12	Isochore - Top of James to Top of Glen Rose Subgroup	6-41
6-13	Isochore - Washita Group	6-43
6-14	Isochore - Woodbine Group	6-47
6-15	Isochore - Top of Pecan Gap to Base of Austin Chalk	6-49
6-16	Isochore - Wilcox Group	6-53
6-17	Regional Mesozoic and Cenozoic Structural Elements	6-56
6-18	Cross Section C-C' Based on Seismic and Well Data	6-59
6-19	Major Fault Trends (on Cretaceous Horizons)	6-65

VOLUME II
LIST OF FIGURES (Continued)

Figure No.	Title	Page
6-20	Cross Section D-D' Based on Seismic and Well Data	6-69
6-21	Cross Section E-E' Based on Seismic and Well Data	6-71
6-22	Cross Section G-G' Based on Seismic and Well Data	6-73
6-23	Quaternary Fault Location and Geologic Map	6-75
6-24	Cross Section of Quaternary Fault at Outcrop	6-76
6-25	Cross Section F-F' Based on Seismic and Well Data	6-81
6-26	Structure - Top of Travis Peak Formation	6-83
6-27	Structure - Top of James	6-85
6-28	Structure - Top of Georgetown Subgroup	6-87
6-29	Structure - Base of Austin Group	6-89
6-30	Structure - Top of Pecan Gap	6-91
6-31	Structure - Top of Nacatoch	6-93
6-32	Structure - Top of Midway Group	6-95
6-33	Regional Epicenter Location Map	6-98
6-34	Location and Comparison of NGS Levels Near the Study Area	6-99
6-35	Earthquake Return Period and Probability of Exceedence Curves from the Study Area	6-105
6-36	Oil and Gas Fields and Lignite Occurences	6-107
6-37	Location of Exploration and Production Wells	6-109

CHAPTER 7

Figure No.	Title	Page
7-1	Oakwood Dome, Salt Structure and Well Location Map	7-14

VOLUME II
LIST OF FIGURES (Continued)

Figure No.	Title	Page
7-2	Oakwood Dome, Cross Section A-A'	7-16
7-3	Oakwood Dome, Cross Section B-B'	7-17
7-4	Oakwood Dome, Caprock Structure Map	7-18
7-5	Oakwood Dome Area, Topographic Map and Data Utilized in Analysis	7-22
7-6	Oakwood Dome Area, Drainage Network	7-24
7-7	Oakwood Dome Area, Geologic Map	7-27
7-8	Oakwood Dome Area, Lineament Map	7-31
7-9	Oakwood Dome, Geologic Cross Section	7-33
7-10	Oakwood Dome Area, Mineral Resource Development	7-44
7-11	Keechi Dome, Salt Structure and Well Location Map	7-47
7-12	Keechi Dome, Cross Section A-A'	7-49
7-13	Keechi Dome, Cross Section B-B'	7-51
7-14	Keechi Dome, Caprock Structure Map	7-53
7-15	Keechi Dome Area, Topographic Map and Data Utilized in Analysis	7-56
7-16	Keechi Dome Area, Drainage Network	7-58
7-17	Keechi Dome Area, Geologic Map	7-59
7-18	Keechi Dome, North-South Cross Section	7-63
7-19	Keechi Dome Area, Cross Sections H-H' and I-I Based on Seismic and Well Data	7-66
7-20	Keechi Dome Area, Lineament Map	7-73
7-21	Keechi Dome Area, Mineral Resource Development	7-80

VOLUME II
LIST OF FIGURES (Continued)

Figure No.	Title	Page
7-22	Palestine Dome, Salt Structure Map and Well Location Map	7-85
7-23	Palestine Dome, Cross Section A-A'	7-87
7-24	Palestine Dome Area, Topographic Map and Data Utilized in Analysis	7-91
7-25	Palestine Dome Area, Drainage Network	7-93
7-26	Palestine Dome Area, Geologic Map	7-95
7-27	Palestine Dome Area, West-East Cross Section Location Map	7-100
7-28	West-East Cross Section Over Palestine Dome	7-101
7-29	Palestine Dome Area, Lineament Map	7-106
7-30	Palestine Dome Area, Mineral Resource Development	7-114

CHAPTER 8

Figure No.	Title	Page
8-1	Location and Extent of Study Area Relative to Trinity River Watershed	8-3
8-2	Regional Drainage and Location of Hydrologic Data Collection Sites	8-7
8-3	Outcrop Map for Selected Hydrogeologic Units	8-13
8-4	Generalized Hydrogeologic Cross Section Through the East Texas Study Area	8-19
8-5	Base of Fresh Water Map	8-22
8-6	Potentiometric Surface of the Wilcox-Carrizo Aquifer	8-23
8-7	Mean Chemical Characteristics of Ground Water in the Fresh Water Aquifer System	8-27
8-8	Mean Chemical Characteristics of Ground Water Underlying the Fresh Water Aquifer System	8-30

VOLUME II
LIST OF FIGURES (Continued)

Figure No.	Title	Page
8-9	Location of Selected High-Capacity Wells	8-34
8-10	Location of Disposal Wells	8-35
8-11	Topography and Drainage in Vicinity of Oakwood Dome	8-39
8-12	Oakwood Salt Dome Location Showing Areas Inundated by Probable-Maximum Flood	8-43
8-13	Hydrogeologic Cross Section Through Oakwood Dome	8-45
8-14	Potentiometric Surface of the Carrizo Aquifer Over Oakwood Dome	8-51
8-15	Relation of Travel Time Along a Vertical Flow Path to Depth in the Vicinity of Candidate Domes	8-53
8-16	Topography and Drainage in Vicinity of Keechi Dome	8-59
8-17	Keechi Dome Location Showing Area Inundated by Probable-Maximum Flood	8-62
8-18	Hydrogeologic Cross Section Through Keechi Dome	8-63

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XIV

GLOSSARY OF GEOLOGICAL TERMS

AGGRADATION - process of building up a surface by deposition.

ALLUVIUM - a general term for clay, silt, sand, gravel or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water; adj. alluvial.

ANGULAR UNCONFORMITY - an unconformity in which the younger overlying sediments rest upon the eroded surface of tilted or folded older rocks.

ANHEDRAL - a crystal in which the crystal faces are neither distinct nor characteristic of the particular mineral or element.

ANHYDRITE - a mineral consisting of anhydrous calcium sulfate: $CaSO_4$.

ANHYDROUS - a substance that is completely or essentially without water; an anhydrous mineral contains no water in chemical combination.

ANTICLINE - a fold, the core of which contains stratigraphically older rocks; it is convex upward; adj. anticlinal; ant. syncline.

AQUICLUDE - a body of relatively impermeable rock that is capable of absorbing water slowly but functions as an upper or lower boundary of an aquifer, and does not transmit water rapidly enough to supply a well or spring; "confining bed" is preferred.

AQUIFER - a body of rock that contains sufficiently saturated permeable material to yield significant quantities of water to wells and springs.

AQUIFUGE - an impermeable body of rock; "confining bed" is preferred.

AQUITARD - a body of impermeable material stratigraphically adjacent to one or more aquifers; "confining bed" is preferred.

AREAL MAP - a geologic map showing the horizontal extent and distribution of rock varieties or rock units exposed at the surface.

ARENACEOUS - sediment or sedimentary rock consisting entirely or partially of sand-size fragments, or having a sandy texture or the appearance of sand.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

ARGILLACEOUS - sediment or sedimentary rock consisting entirely or in part of clay-size particles or clay minerals.

ASPHALTIC ROCK - a porous rock that has been impregnated naturally with asphalt.

BENTONITE - a general term for the montmorillonitic clay minerals derived from volcanic ash.

BIOSPHERE - all the area occupied by or favorable for occupation by living organisms including parts of the lithosphere, hydrosphere, and atmosphere. For considerations related to salt dome hydrology, the scope of the biosphere is expanded to include man and his food chain, i.e., from drillable depths, ±9,144 meters (± 30,000 ft) deep in the earth's crust, to the base of the stratosphere.

BIOSTRATIGRAPHY - stratigraphy based on the paleontologic aspects of rocks or stratigraphy with paleontologic methods.

BITTERNS - a natural solution, in an evaporite basin, that resembles a saltworks liquor, especially in its high magnesium content.

BLOCK FAULTING - a type of normal faulting in which the crust is divided into structural or fault blocks of different elevations and orientations.

BLOWOUTS - gaseous outbursts that may occur within a salt mine at the time of blasting and are confined to anomalous zones.

BOUDINAGE - a structure in which an original, continuous, competent layer or bed between less competent layers has stretched, thinned, and broken at regular intervals into bodies resembling boudins (sausage links) elongated parallel to the fold axis.

BOUGUER ANOMALY - a gravity anomaly calculated by allowing for the attraction effect of topography but not for that of isostatic compensation.

BOUNDARY SHEAR ZONES - a zone that forms the boundary between a spine of salt and the outside of the salt dome, or between two spines.

BRECCIATED - said of a rock structure marked by an accumulation of angular fragments, or of an ore texture showing mineral fragments without notable rounding.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

BRINE WELL - a salt well from which water is taken to be evaporated for making salt.

CALCITE - a common rock-forming mineral: $CaCO_3$.

CALIPER LOG - a graphic record which shows, to scale, the diameter of a drilled hole.

CAPABLE FAULT - a fault on which movement at or near the ground surface has occurred at least once within the past 35,000 years, or has had movement of a recurring nature within the past 500,000 years; a fault which has been directly correlated with seismic events.

CAPROCK - a hard rock layer, usually anhydrite, calcite, and gypsum, commonly found overlying the salt stock.

CARBONATE - a sediment formed by the organic or inorganic precipitation from aqueous solution of carbonates of calcium, magnesium or iron.

CARBONIC ACID - A weak naturally occurring acid (H_2CO_3), formed from atmospheric water and carbon dioxide.

CATACLASIS - rock deformation accomplished by fracture and rotation of mineral grains or aggregates without chemical reconstitution.

CLASTIC - a rock or sediment composed principally of broken fragments that are derived from pre-existing rocks or minerals and have been transported individually.

COMMON DEPTH POINT - a point at depth at which seismic reflections are produced at different offset distances on several profiles.

COMPETENT - said of a bed or stratum that is able to withstand the pressures of folding without flowage or change in original thickness.

COMPRESSIVE STRENGTH - a material's resistance to the maximum compressive stress that can be applied to a material, under given conditions, before failure occurs.

CONDUCTANCE - a measurement of salinity or salt (electrolyte) concentration of a fluid.

CONDUCTIVITY - usually refers to electricity or ionic transfer as in an electrolyte; or thermal conductivity, transfer of heat.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

CONFINING BED - a zone or bed of impermeable or distinctly less permeable material adjacent to one or more aquifers; see aquitard.

CONFORMABLE - an unbroken sequence of strata in which the layers are formed one above the other in parallel order by regular uninterrupted deposition under the same general conditions.

CONTOUR MAPS - an illustration of the form and distribution of various types of data produced by joining points of equal value; e.g., structural, isopach, topographic.

COQUINA ROCK- a detrital limestone composed wholly or chiefly of mechanically sorted fossil debris; adj. coquinoid.

CORE - a cylindrical or columnar piece of solid rock or section of soil taken as a sample of an underground formation by a special hollow-type drill bit.

CREEP - slow deformation of solid rock resulting from a small, constant stress acting over a long period of time.

CUESTA - a hill or ridge with a gentle slope (dip slope) on one side and a steep slope (scarp face) on the other.

DECLIVITY - a descending slope.

DEGRADATION - the general lowering of the surface of the land by erosive processes.

DELTA - an alluvial deposit, usually triangular, at the mouth of a river.

DENDRITIC DRAINAGE PATTERN - drainage pattern characterized by irregular branching.

DENUDATION - the process of exposing strata by erosion of overlying materials.

DEPOCENTER - an area or site of maximum deposition.

DESOMANTICLINE - a series of structural highs and lows aligned along a linear axis, resembling a chain or string of beads.

DETRITUS - a collective term for loose rock and mineral material that is worn from an older rock by mechanical means and moved from its place of origin.

DIAGENESIS - The process by which all the chemical, physical, and biologic changes, modifications or transformations are undergone by a sediment after its initial deposition, and during and after its lithification, exclusive of surficial alteration and metamorphism.

DIAPIR - a dome or anticlinal fold, the overlying rocks of which have been ruptured or pierced by the squeezing out of the plastic core material, such as salt or an incompetant shale.

DIAPIRISM - the process of piercing or rupturing of domes or uplifting overlying rocks by core material, such as salt.

DIP - the angle that a bedding or structural surface makes with the horizontal plane, measured perpendicular to the strike.

DISCONFORMITY - an unconformity in which the older rocks remained essentially horizontal during erosion or cessation of deposition during simple vertical rising and sinking of the crust.

DISSOLUTION - a space or cavity in or between rocks formed by the solution of part of the rock material.

DOME - see salt dome.

DOWNCUTTING - stream erosion in which the cutting is directed in a downward direction.

DOWNDIP - a direction that is downwards and parallel to the dip of a structural surface.

DOWN-HOLE GEOPHYSICAL LOGGING - the process of lowering an instrument into a borehole or well and recording continuously on a meter at the surface some physical property of the rock material being logged.

DRAG FOLDS - minor folds that form in an incompetent bed when the competent beds on either side of it move in such a way as to subject it to a couple; any fold that is a subsidiary part of a larger fold.

EARTHQUAKE INTENSITY/ACCELERATION - a measure of the effects of an earthquake at a particular place on humans and/or structures.

ENTRENCHMENT - the process of a stream eroding downward so as to form a trench.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

EPICENTER - the point on the Earth's surface which is directly above the focus of an earthquake.

EPICENTRAL INTENSITY - a measure of an earthquake's intensity at its epicenter.

EQUIDIMENSIONAL - a textural term describing a material in which all crystals or grains are essentially the same size.

ESCARPMENT - a long, more or less continuous cliff or relatively steep slope facing in one general direction, breaking the general continuity of the land by separating two level or gently sloping surfaces.

EUHEDRAL - a crystal in which the crystal faces are very distinct and characteristic of the particular mineral or element.

EUSTATIC - pertaining to worldwide changes of sea level that affect all of the oceans.

EVAPORITE - a nonclastic sedimentary rock composed primarily of minerals precipitated from a saline solution.

EXFOLIATION - the process by which thin concentric shells are successively broken loose from the bare outer surface of a large rock mass.

EXTERNAL SHEATH ZONE - a zone that forms the boundary between a spine of salt and the outside of the salt dome type of boundary shear zone.

EXTRUSION - the igneous process of emitting lava onto the Earth's surface; also, the rock so formed.

FACIES - the sum of all primary lithologic and paleontologic characteristics exhibited by a sedimentary rock and from which its origin and environment of formation may be inferred; the general aspect, nature or appearance of a sedimentary rock produced under or affected by similar conditions.

FAULT - a surface or zone of rock fracture along which there has been displacement.

FERRUGINOUS - pertaining to or containing iron.

FIRST ORDER LEVELING - spirit leveling to establish a horizontal line of sight of high precision and accuracy.

FISSILE - capable of being easily split along closely spaced planes.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

FLAGGY ROCK - rock that tends to split into layers 1 to 5 cm (0.39 to 1.96 in) in thickness.

FLEXURE - a fold formed by warping or other gentle deformation rather than by compression; c.f. hinge fault.

FLEXURE FAULT - a fault that originally occurred as a flexure.

FLUVIATILE - pertaining to river flow and river action.

FORMATION - a basic convenient unit of rocks, of considerable thickness and extent, used in mapping, describing, or interpreting the geology of a region, and the only formal classification that is used for completely dividing the whole geologic column all over the world into named units on the basis of lithology.

FORMATION PACKER - a drill-stem testing apparatus utilized in boreholes to isolate a particular zone of interest in the rock section by inflating flexible steel-meshed rubber cushions against the sides of the hole, thus permitting formation fluids to be sampled.

FRACTURE - general term for any break or separation in a rock.

FRIABILITY - the ease with which a material can be crumbled.

GEOHYDROLOGY - a term referring to the flow characteristics of subsurface waters; c.f. ground-water hydrology.

GEOID - the "figure of the Earth" considered as a sea level surface extended continuously through the continents.

GEOLOGIC OR STRATIGRAPHIC CROSS SECTIONS - a diagram that shows geologic features transected by a given plane (usually a vertical plane).

GEOLOGIC STRUCTURE - the general disposition, attitude, arrangement, or relative positions of the rock masses of a region or area; the sum total of the structural features of an area; also used to designate any physical arrangement of rocks, such as an anticline or fault, due to earth forces.

GEOMORPHOLOGY - the science that treats the general configuration of the Earth's surface and its relationship to geologic forces. The interpretative study of landforms; see physiography.

GEOPHYSICAL LOGS - a log obtained by lowering an instrument into a borehole or well, while recording continuously on a meter at the surface some physical property of the rocks through which it passes.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

GEOPRESSURED - subsurface condition in which the fluid pressures exceed the normal hydrostatic pressures, due generally to the weight of the overburden.

GEOSYNCLINE - a mobile downwarping of the crust of the Earth, measured in scores of kilometers, which is subsiding as sedimentary and volcanic rocks accumulate to a thickness of thousands of meters; adj. geosynclinal.

GLACIO-ISOSTASY - the state of hydrostatic equilibrium in the Earth's crust as influenced by the weight of glacial ice.

GLAUCONITE - a dull green, amorphous, and earthy or granular mineral of the mica group.

GOUGE - a thin layer of soft rock material between a salt plug and adjacent strata created by cataclasis during diapirism.

GRABEN - an elongated, relatively depressed crustal unit or block that is bounded by faults along its sides; down-dropped fault block; c.f. horst.

GRAIN DENSITY - specific gravity of the grains composing a sediment or sedimentary rock.

GROUND WATER - that part of the subsurface water which is in the zone of saturation.

GROUP - a major rock-stratigraphic unit, next higher in rank than formation; consisting wholly of two or more contiguous or associated formations having significant lithologic features in common.

GROWTH FAULT - a fault in sedimentary rocks that forms contemporaneously and continuously with deposition.

GYPSUM - a mineral consisting of hydrous calcium sulfate: $CaSO_4 \cdot 2H_2O$.

HALITE - native salt; the mineral sodium chloride: $NaCl$.

HALOKINETICS - a general term for the study of the structure and mechanism of salt movements.

HALO-TECTONIC - pertaining to the forces resulting in salt movement.

HECTARE - a metric unit of land area equal to 10,000 square meters or 2.471 acres.

HEMATITE - a common iron mineral consisting of ferrous oxide: Fe_2O_3.

HIATUS - a break or interruption in the continuity of the geologic record.

HINTERLAND - an area bordering, or within, an orogenic belt on the internal side, away from the direction of overfolding and thrusting.

HOMOCLINAL SHEAR ZONES - a tabular zone of rock that has been brecciated by parallel fracture along rock units which have the same dip.

HOMOGENEOUS SEISMICITY - seismic activity equally dispersed throughout its occurrence.

HORST - an elongated, relatively uplifted crustal unit or block that is bounded by faults on its long sides; uplifted fault block.

HOST ROCK - a body of rock which includes relatively small amounts of other rocks or mineral deposits.

HYDROGEOLOGY - the science that deals with subsurface waters and related geologic aspects of surface waters.

HYDROLOGY - the science that deals with continental water, its properties, circulation, and distribution on and under the Earth's surface and in the atmosphere.

IGNEOUS - said of a rock or mineral that solidified from a molten or partially molten state, i.e. from a magma; contrasted to sedimentary.

INDURATED - condition of a compact rock or soil hardened by the action of pressure, cementation, or especially heat.

INLIER - an area or exposed group of rocks surrounded by outcrops of younger rocks.

INTENSITY RECURRENCE FUNCTION - a statistically determined relationship expressing the probabilistic likelihood of experiencing a certain [earthquake] intensity as a function of time.

INTERFLUVES - the areas between rivers; esp. the relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction and belonging to the same general drainage basin or watershed.

INTERGLACIAL - pertaining to the time interval between two successive glacial epochs, or between two glacial stages.

INTERNAL BOUNDARY ZONE - a zone which forms the boundary between two salt spines.

INUNDATED - to be covered with water; flooded.

ISOCHORE - a line drawn through equal interval between two beds or other places.

ISOCHORE MAP - a map that shows the varying interval between two designated stratigraphic planes or horizons, possibly including one or more unconformities. c.f. isopach map.

ISOCLINAL FOLDS - a fold in which the limbs have been so compressed that they have the same dip.

ISOPACH - a line drawn on a map through points of equal thickness of a designated stratigraphic unit.

ISOPACH MAP - a map that shows the thickness of a designated stratigraphic unit; c.f. isochore map.

ISOSEISMAL - a line connecting points on the Earth's surface at which earthquake intensity is the same.

ISOSTASY - the condition of equilibrium [comparable to floating] of the units of the brittle crust above the denser plastic mantle. Principle of equilibrium level between coastal segments of equal area having same mass.

ISOSTATIC (SEA LEVEL CHANGES) - changes in sea level resulting from adjustments in the Earth's crust to maintain equilibrium among units of varying mass and density.

JUVENILE WATER - term applied to water that is known to be derived directly from magma and comes from the Earth's interior to the surface for the first time.

KAOLINITE - a common, white to grayish or yellowish clay mineral of the kaolin group: $Al_2 Si_2 O_5 (OH)_4$.

KNICKPOINT - a point of abrupt change in the longitudinal profile of stream valleys.

LENS - a geologic deposit bounded by converging surfaces, thick in the middle and thinning toward the edges.

LENTIL - a minor rock stratigraphic unit of limited geographic extent, being a subdivision of a formation and similar in rank to a member, and thinning out in all directions.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

LEVELING - the operation of determining the comparative altitude of different points on the Earth's surface.

LIGNITE - a brownish-black coal that is intermediate in coalification between peat and subbituminous coal.

LIMESTONE - a class of rock which is composed of at least 80 percent of calcium or magnesium carbonates.

LIMONITE - a general term for a group of brown, amorphous, naturally occurring hydrous ferric oxides not specifically identified.

LINEAMENT - an alignment of surficial features that is structurally controlled, such as stream beds, vegetation or soil or rock tone that are so controlled; commonly observed on aerial photos or topographic maps.

LINEAR - a straight or gently curved physiograhic feature on the Earth's surface.

LINEATION - a general term for any linear feature of whatever scale in a rock.

LITHOLOGY - the physical description of rocks on the basis of such characteristics as color, mineralogic composition, and grain size.

LITHOSPHERE - the solid portion of the earth, as compared with the atmosphere and hydrosphere.

LUTITE - sediment or sedimentary rock consisting principally of clay or clay-sized particles.

MARL - an old term loosely applied to a variety of materials, most of which occur as soft, loose, earthy, and semifriable or crumbling unconsolidated deposits consisting chiefly of an intimate mixture of clay and calcium carbonate in varying proportions, formed under either marine or fresh-water conditions.

MASSIFS - an embryonic salt dome rising from its source bed, still at depth.

MICRITE - a limestone with a very fine subcrystalline texture.

MODIFIED MERCALLI INTENSITY - scale (from I to XII) for evaluating earthquake shocks.

METAMORPHIC - any rock derived from preexisting rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, etc.

MHO - a unit of electical conductance equal to the reciprocal of ohm.

MICROFOSSIL - a fossil too small to be studied without the aid of a microscope.

MICROMHO - mho x 10^{-6}.

MICROCRYSTALLINE - said of the texture of a rock consisting of or having crystals that are small enough to be visible only under a microscope; also said of a rock having such a texture.

MICROSEISMIC MONITORING - earthquake measurement or observation by instrumental means of shocks below the sensitivity threshold of the conventional seismograph.

MINERALOGY - the study of minerals, their formation and occurrence, their properties and composition, and their classification.

NEOGENE - an informal usage for the period of time incorporating the Miocene and Pliocene of the Tertiary Period.

NERITIC - pertaining to the ocean environment or depth zone between low-tide level and 100 fathoms, or between low-tide level and approximately the edge of the continental shelf.

NONCONFORMITY - an unconformable contact between sedimentary rocks lying upon an eroded surface of older igneous or metamorphic rocks.

NORMAL FAULT - a fault in which the hanging (upper) wall appears to have moved downward relative to the footwall. The angle of the fault is usually 45-90°.

OFFLAP - the reverse of transgressive onlap, occurring where a shoreline has retreated seaward and progressively younger strata have been deposited in layers offset seaward; a type of overlap.

ONLAP - extension of successive stratigraphic units beyond the marginal limits of their predecessors onto older rocks as in the deposits of a trangressing sea; a type of overlap.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

OOLITHS - one of the small, round accretionary bodies in a sedimentary rock, usually calcium carbonate.

OOLITE - a sedimentary rock usually a limestone, made up chiefly of ooliths cemented to others.

OOLITIC LIMESTONE - an even textured limestone composed almost entirely of relatively uniform calcareous ooliths.

OROGENIC BELT - a linear region that has been subjected to folding and deformation during an orogenic cycle.

OROGENY - the process by which rock structures in mountainous areas were formed.

OUTLIER - an area or group of rocks surrounded by outcrops of older rocks.

OVERBURDEN - the loose soil, silt, sand, gravel or other unconsolidated material overlying bedrock.

OVERCONSOLIDATION - consolidation resulting from desiccation or from pressure of overburden that has since been removed by erosion.

OXBOW LAKE - the crescent-shaped body of standing water situated by the side of a stream in the abandoned channel (oxbow) after the stream formed a neck cutoff and the ends of the original bend were silted up.

PALEOGENE - an informal usage for the interval of geologic time incorporating the Paleocene, Eocene, and Oligocene of the Tertiary Period.

PALEOGEOGRAPHIC MAP - a map that shows the reconstructed physical geography at a particular time in the geologic past.

PALEONTOLOGY - the study of life in past geologic periods, based on fossil plants and animals and including phylogeny, their relationships to existing plants and animals, and the chronology of the Earth's history.

PELLET - a small, usually rounded, aggregate of accretionary material; also fecal matter from fossil organisms.

PELLETAL LIMESTONE - a limestone characterized by abundant pellets.

PENCIL - long, slender pieces of rock (anhydrite) resembling pencils.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

PENEPLAIN - a low, nearly featureless and gently undulating or almost-plane land surface of considerable area.

PERMEABILITY - the property or capacity of porous rock, sediment, or soil for transmitting a fluid without impairment of the structure of the medium.

PETROFABRIC - the textural features of a rock.

PETROLOGY - that branch of geology dealing with the origin, occurrence, structure and history of rocks, especially igneous and metamorphic rocks.

PETROGRAPHY - the branch of geology dealing with the description and classification of rocks, especially igneous and metamorphic rocks.

PHYSIOGRAPHY - the descriptive study of landforms; see geomorphology.

PIERCEMENT DOME - see diapir.

PIERCEMENT STAGE - a stage of salt dome development in which the salt rises vertically, penetrating the overlying strata.

PIEZOMETRIC SURFACE - see potentiometric surface.

PILLOWING - a stage of salt dome development in which the salt is said to move laterally into mounds or "pillows."

PINCH-OUT - the termination or end of a stratum, vein, or other body or rock by tapering or progressively narrowing to extinction.

PLASTICITY - the property of a material that enables it to undergo permanent deformation without appreciable volume change or elastic rebound, and without rupture.

POTASH - potassium carbonate, K_2CO_3.

POROSITY - the property of a rock, soil, or other material containing interstices, and the ratio of the volume of its interstices to its total volume.

POTENTIOMETRIC SURFACE - an imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well; c.f. piezometric surface.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

PRODELTA - that part of the delta that is below the effective depth of wave erosion, lying beyond one delta front and sloping gently down to the floor of one basin into which the delta is advancing.

PROLATE - designating the shape of a solid, especially of a spheroid having its polar axis longer than its equatorial diameter; cigar-shaped.

QUAQUAVERSAL DIP - dipping outward in all directions from a central point, as a dome in stratified rocks.

RADIONUCLIDE - a radioactive species of atom characterized by the number of neutrons and protons in its nucleus; a product of radioactivity.

REDBEDS - sedimentary strata composed largely of clastic materials that are predominantly red in color due to the presence of hematite.

RELICT - a relief feature or rock remaining after other parts have disappeard.

REMOTE SENSING - in a restricted sense the practice of data collection in the wavelengths from ultraviolet to radio regions; a practical outgrowth of airborne photography.

RESIDUAL GRAVITY - the difference between theoretical, calculated, and observed terrestrial gravity, measured in milligals.

RESISTIVITY - the resistance to electrical current of a rock unit, measured instrumentally as a reconnaissance method of determining the nature of rocks in the shallow subsurface.

RIFT - a narrow cleft, fissure, or other opening in rock made by cracking or splitting; a large strike-slip fault parallel to regional structures.

RIFT BASIN - a deep central cleft in the crest of a mid-oceanic ridge.

RIFT VALLEY - valley produced by subsidence of a block bounded by two rifts.

RIM SYNCLINES - downfolds that tend to develop around the periphery of salt domes due to sagging of the overlying strata into a circular void created by the removal of salt from the source strata.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

SALINE - a natural deposit of common salt or of any other soluble salt, e.g., an evaporite; pertaining to, consisting of, or containing salt; refers also to various features related to a natural evaporitic environment, e.g., playa, salt lake, salt pan, etc.

SALT CORE - a cylindrical sample of salt obtained by drilling into a rock salt body with a hollow drill bit; also, the central portion of salt stock.

SALT DOME - a structure resulting from the upward movement of a salt mass.

SALT STOCK - the salt mass portion of a salt dome structure.

SANDSTONE - a cemented or otherwise compacted detrital sediment composed predominantly of quartz grains.

SEDIMENTARY ROCK - a rock resulting from the consolidation of loose sediment that has accumulated in layers.

SEISMIC - pertaining to an earthquake or Earth vibration, including those that are artificially produced.

SEISMICITY - the phenomenon of Earth movements.

SEISMIC REFLECTION - a geophysical technique which measures the time of energy from a seismic source which has been reflected.

SEISMIC SURVEY - the gathering of data from artificially induced vibrations.

SEISMOLOGY - the study of earthquakes; by extending the study of the structure of the interior of the Earth via both natural and artificially generated seismic signals.

SEISMOTECTONIC REGION - a region characterized by a relative consistency of historical seismicity and of structural activity among geologic features contained therein.

SERIES - a time-stratigraphic unit generally classed next in rank below a system, and above a stage, properly based on a clearly designated stratigraphic interval in a type area.

SHEAR - strain resulting from compressive stresses that cause or tend to cause contiguous parts of a body to slide relative to each other in a direction parallel to their plane of contact; usually at an angle other than perpendicular to the direction of stress.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

SHALE - a laminated sediment in which the constituent particles are predominantly of the clay grade.

SHEAR MODULUS/S-WAVE VELOCITY -rigidity or shear modulus is a measure of the stress-strain ratio for a simple shear.

SHEAR WAVES - that type of seismic body wave which is propagated by a shearing motion of material so that there is oscillation perpendicular to the direction of propagation.

SHEATH (Lighology)- rock material, commonly shale, which surrounds or encompasses a salt plug.

SHEATH (Struct.)- pertaining to the external zone of a salt stock in which expansion of the salt has taken place, increasing the porosity and permeability.

SIDERITE - a rhombohedral mineral: $FeCO_3$.

SIDETRACKING - the practice of diverting multiple subsurface drill-holes from a single surface drill-hole.

SINKHOLE - a general term for a depression in an area of karst topography that is formed either by the solution of the surficial limestone or by the collapse of underlying caves.

SLABBING/SPALLING (OF WALLS) - the natural process of sloughing of large slabs of salt from the walls of mine workings.

SLOPE STABILITY - the quality of permanence or resistance of a natural or artificial slope to failure by landsliding.

SOLUTION - a process of chemical weathering by which rock material passes into solution.

SONIC LOG - an acoustic log continuously recording travel time of sound from the surface to an instrument lowered down a borehole.

SPALLING - see slabbing/spalling.

SPINE - a vertical protrusion of a salt stock which may or may not move upward at a different rate than the rest of the stock.

STACKING - a statistical method of processing seismic records that has the effect of averaging the intensity of the rays of energy from a single reflection point, while reducing the relative amount of noise or signal interference.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

STALACTITE - a cylindrical or conical deposit of minerals hanging from the roof of a cavern.

STALAGMITE - a column or ridge of material rising from the floor of a cavern or mine, caused by water dripping down from above.

STRADDLE-PACKER - a drill-stem testing apparatus utilized in boreholes to isolate a zone or interval of interest in the rock section (see formation packer).

STRATIGRAPHY - the arrangement of strata especially as to geographic position and chronological order of sequence: the branch of geology that deals with the description of minor and major divisions of rock.

STRATUM - a tabular or sheet-like mass, or a single and distinct layer, of monogeneous or gradational sedimentary material, distinguishable from mass above and below.

STREAM REACH - arbitrary lengthwise section of a stream.

STRIKE - the direction or trend of a structural surface with the horizontal plane.

STRUCTURAL GEOLOGY - that branch of geology that deals with the form, arrangement, and internal structure of the rocks.

STRUCTURE - the general disposition, attitude, arrangement, or relative positions of the rock masses of a region or area.

SUBAERIALLY - occurring beneath the atmosphere or in the open air; esp. said of conditions and processes (such as erosion) that exist or operate on or immediately adjacent to the land surface; c.f. - subaqueous.

SUBHEDRAL - a crystal in which the crystal faces are intermediate between distinct and non-distinct.

SYLVITE - a white or colorless isometric mineral, potassium chloride (KCl). It is the principal ore of potassium.

SYNCLINE - a fold, the core of which contains the stratigraphically younger rocks; it is concave upward.

SYNTHETIC SEISMOGRAM - artificial seismogram produced by computer from the acoustic velocity log of a well.

TARRY OIL SEEP - a place of emergence of tar-like petroleum as a result of the slow migration from its buried source, through minute pores or fissures.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

TECTONIC - dealing with the rock structure and external forms resulting from the deformation of the earth's crust; as applied to earthquakes it is used to describe shocks not due to volcanic action or the collapse of caverns or landslides.

TECTONIC STRUCTURE - a large scale dislocation in or distortion of the Earth's crust.

TERRACE - any long, narrow, relatively level, or coastward gently inclined surface bounded on one edge by a steeper descending slope and also along the other by a steeper ascending slope; a large bench or step-like ledge.

TERRIGENOUS - produced from or of the Earth, terrigenous deposits are sediments derived from the land and deposited in shallow marine area.

TERRESTRIAL - pertaining to the land surface of the earth; terrestrial deposits are those made on land, above tidal reach.

THROW - on a fault, the amount of vertical displacement.

TILT - the angle at the perspective center between the plumb line and the perpendicular from the interior perspective center to the plane of a photograph.

TILTMETER - an instrument that measures slight changes in tilt of the Earth's surface.

TUFF - a compacted pyroclastic deposit of volcanic ash and dust that may contain up to 50% sediments such as sand or clay.

TUFFACEOUS MATERIAL - sediment containing up to 50% tuff.

UNCONFORMABLE - strata or stratification exhibiting the relation of unconformity to the older underlying rocks.

UNCONFORMITY - a substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic succession.

UPDIP REGION - a direction which is upwards and parallel to the dip of a structure or surface.

UPLIFT - a structurally high area in the crust produced by positive movements that raise or upthrust the rocks.

VALES - a rift valley or tectonic valley; also land between two parallel cuestas.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

VIRGIN ROCK - fresh rock that has not been weathered.

VOID RATIO - the ratio of the volume of void space to the volume of solid substance in any material consisting of voids and solid material.

VUG - a cavity, often with a mineral lining of different composition from that of the surrounding rock.

WATERSHED - the area contained within a drainage divide above a specified point on a stream.

WOLD - a range of hills produced from differential erosion from inclined sedimentary rocks; a cuesta.

XENOLITH - rock fragments contained in an igneous body of rock which are foreign to the host rock; inclusion.

CONVERSION FACTORS

The conversion factors used in this report are based on the following table. In most instances, the metric-to-standard measurement conversions represent rounded-off figures in this report.

To convert from	To	Multiply by
millimeter (mm)	inch (in)	0.03937
meter (m)	foot (ft)	3.281
kilometer (km)	mile (mi)	0.6214
meter^2 (m^2)	foot^2 (ft^2)	10.76
kilometer^2 (km^2)	mile^2 (mi^2)	0.3861
hectare (-)	acre (-)	2.471
kilogram (kg)	pound (lb)	2.205
tonne (-)	ton (-)	0.893
liter (l)	gallon (gal)	0.2642
kilometers^3 (km^3)	miles^3 (mi^3)	0.244
kilopascal (kPa)	atmosphere (atm)	0.009869
milligrams per liter (mg/l)	parts per million (ppm)	1.0
liter per second (l/sec)	gallon per minute (gal/min)	15.85

ABBREVIATIONS AND ACRONYMS

AEC	Atomic Energy Commission
BEG	Texas Bureau of Economic Geology
BMI	Battelle Memorial Institute
BNI	Bechtel National, Inc.
DOE	Department of Energy
ERTS	Earth Resources Technology Satellite
FEA	Federal Energy Administration
LANDSAT	Earth Resources Technology Satellite (formerly ERTS)
LETCo	Law Engineering Testing Company
LSU/IES	Louisiana State University/Institute for Environmental Studies
MGAI	Mellen Geological Associates, Inc.
MM	Modified Mercalli
MMI	Modified Mercalli Intensity
MSGS	Mississippi State Geological Survey
MSL	Mean Sea Level
NAS	National Academy of Science
NRC	Nuclear Regulatory Commission
NSAI	Netherland, Sewell and Associates, Incorporated
NWTS	National Waste Terminal Storge
ONWI	Office of Nuclear Waste Isolation of Battelle Memorial Institute
ORNL	Oak Ridge National Laboratories
OWI	Office of Waste Isolation/Union Carbide Corp.
SCS	Soil Conservation Service
TAB	Technical Advisory Board
TNRIS	Texas Natural Resource Information System
USGS	United State Geological Survey
USM	University of Southern Mississippi

6 GEOLOGIC CHARACTERIZATION OF THE EAST TEXAS STUDY AREA

The geologic characterization of the East Texas Study Area involves the description of the physiography, geomorphology, stratigraphy, structure, geological history, seismicity, and mineral resources. These studies lead to a fundamental understanding of the geology of the study area. This understanding is the basis for evaluating the key geologic items bearing on the tectonic stability of the area and on dome growth of the selected salt domes. Based upon the lithology of the geologic column, the studies were also designed to determine the hydrologic characteristics of certain areas.

6.1 DESCRIPTION OF THE EAST TEXAS STUDY AREA

The East Texas Study Area covers approximately 3,367 km^2 (1,300 mi^2) in the southern part of the East Texas Basin, including portions of Anderson, Freestone, Houston, and Leon Counties. The area, located entirely within the Gulf Coast Plain, is an oval enclosing the three salt domes originally selected in Texas for study, i.e., Keechi, Oakwood and Palestine (Figure 6-1).

The topography of the study area, characterized by numerous hills, rolling uplands, the drainage systems of the Trinity and Neches Rivers, and small lakes, reflects relief typical of the Gulf Coast Plain. The ground surface, sloping southward and southeastward, is dissected by a moderately dense drainage network (Figure 6-2).

There are no large natural lakes within the study area, although several small oxbow lakes, a few tens of acres in size, and numerous small stock ponds are found on the flood plain of the Trinity and Neches Rivers. The only large man-made lake is Fairfield Lake along the western boundary.

Land use falls into three major categories: woodlands, agricultural, and urban. The urban areas include incorporated cities, fringe areas adjacent to the urban areas, industrial sites, and rural settlements. Agricultural areas include cropland, rangeland, pastureland, and idle land. The study area is equally divided between woodlands and agricultural land, whereas urban areas entail less than one percent of the area.

An extensive network of highways, farm-to-market roads, and county roads has been developed in the study area (Figure 6-1). The major north-south highway systems are Interstate 45/U.S. 75 and U.S. 287/Texas 19, and the major east-west highways are U.S. 79 and U.S. 84. Three of these major routes to Palestine are paralleled by the Missouri Pacific Railroad, including U.S. 79 from the southwest, U.S. 84 from the northeast, and U.S. 287/Texas 19 from the south. All state and U.S. highways within the study area are primary roads with hard surfaces. Although farm-to-market roads are generally hard-surfaced, they are designated secondary roads, as are county roads, which are generally light-duty gravel roads covered by glauconitic ironstone road metal with or without a seal coat.

Since the oil boom in East Texas in the 1930's, the production of petroleum and the manufacture of oil and gas products

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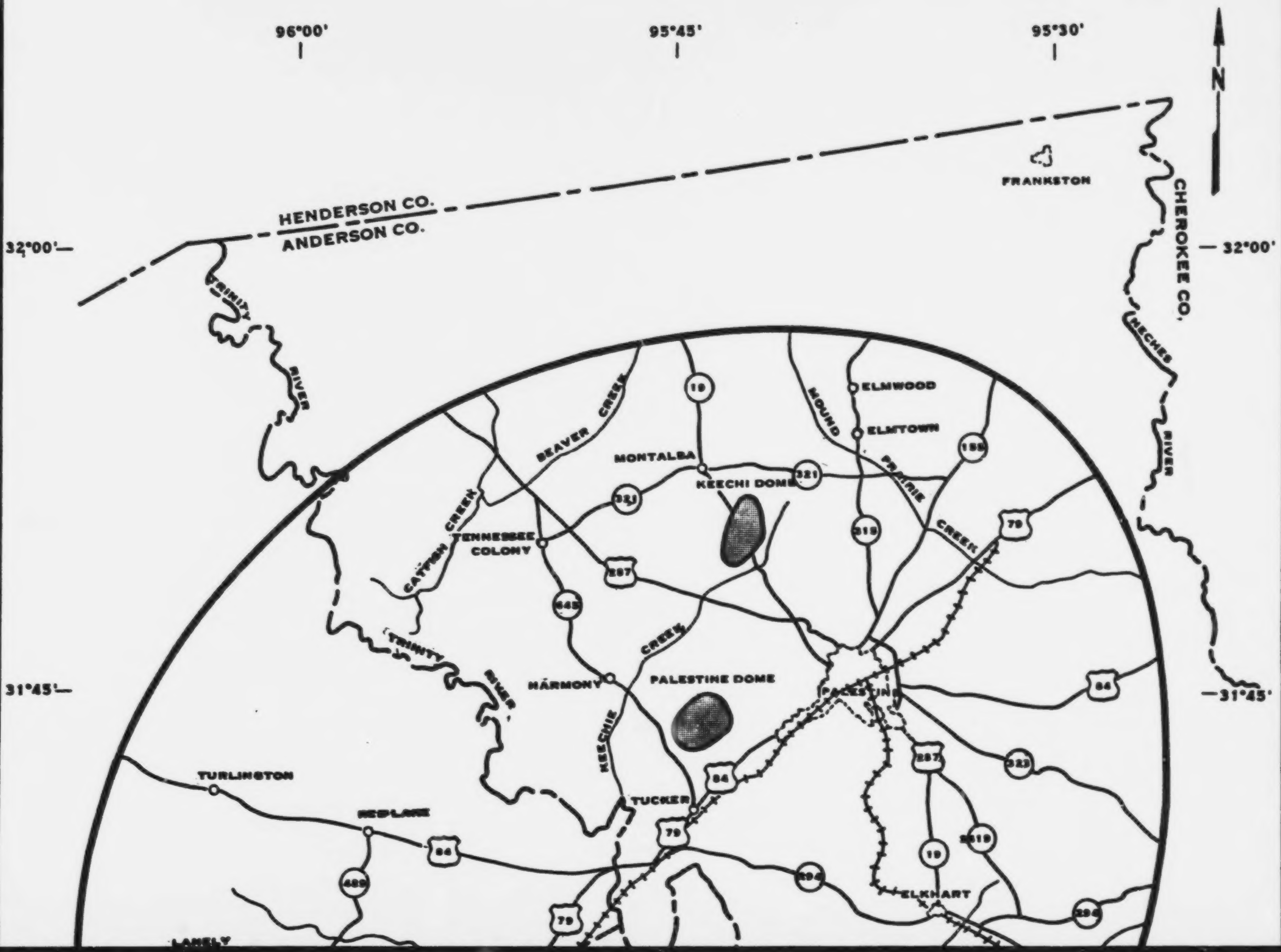
BES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NECHES
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19
ELMWOOD
ELMTOWN
MOUND
PRAIRIE
CREEK
155
BEAVER CREEK
MONTALBA
321
KEECHI DOME
321
CATFISH CREEK
TENNESSEE COLONY
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TRINITY
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PALESTINE DOME
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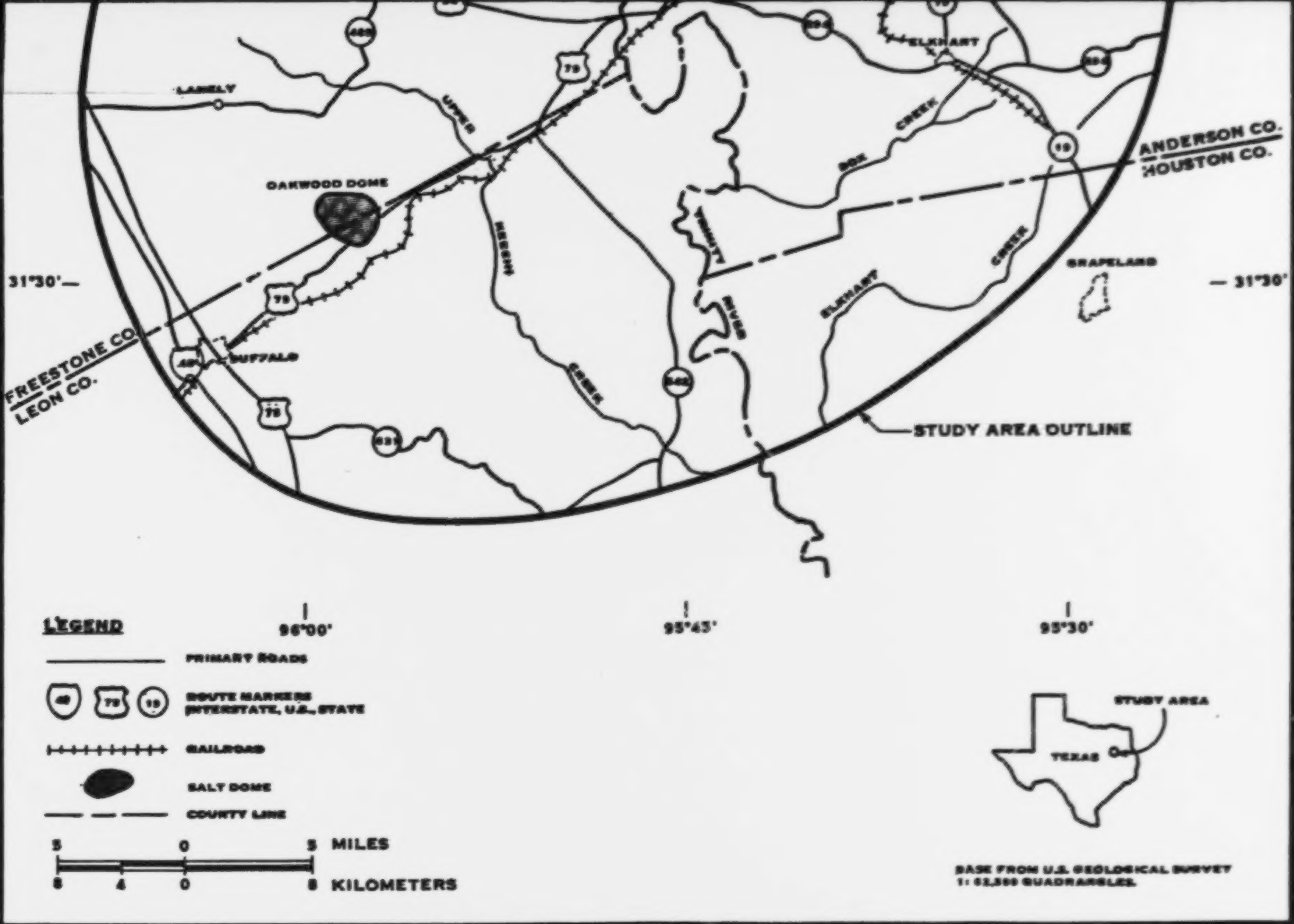
FIGURE 6-1



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HOUSTON CO.
CREEK
GRAPELAND
ELKHART
31°30'
31°30'
79
FREESTONE CO.
LEON CO.
45
BUFFALO
79
831
542
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
PRIMARY ROADS
45
79
19
ROUTE MARKERS (INTERSTATE, U.S., STATE)
RAILROAD
SALT DOME
COUNTY LINE
5
0
5
MILES
8
4
0
8
KILOMETERS
STUDY AREA
TEXAS

BASE FROM U.S. GEOLOGICAL SURVEY
1: 62,500 QUADRANGLES.

PREPARED
DATE 8/15/80
REVISED GHF
DATE 11/9/81
REVISED
DATE
APPROVED
DATE 8/15/80

T-1059-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA . GEORGIA

EAST TEXAS STUDY AREA
LOCATION MAP

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FIGURE 6-1

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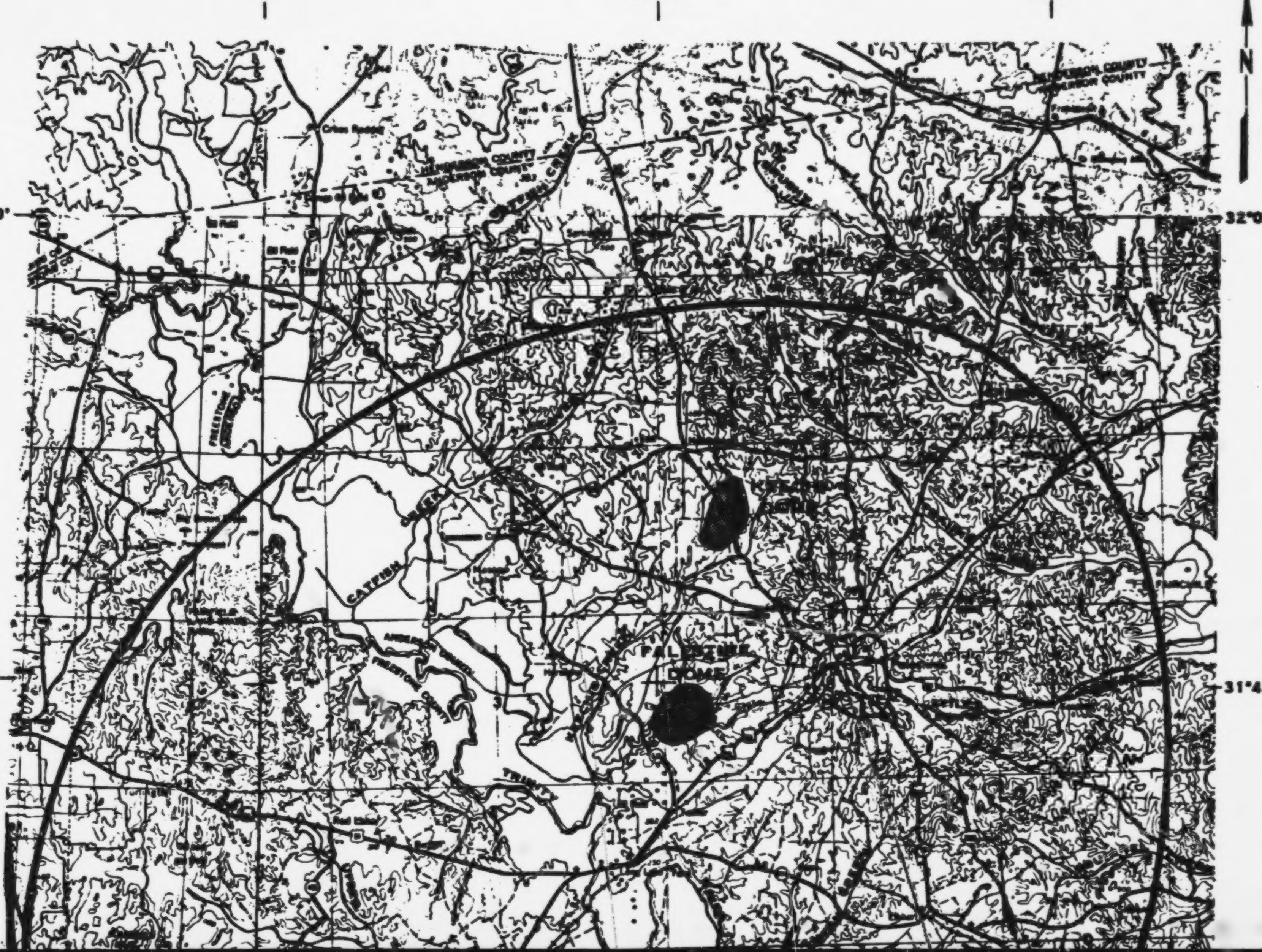
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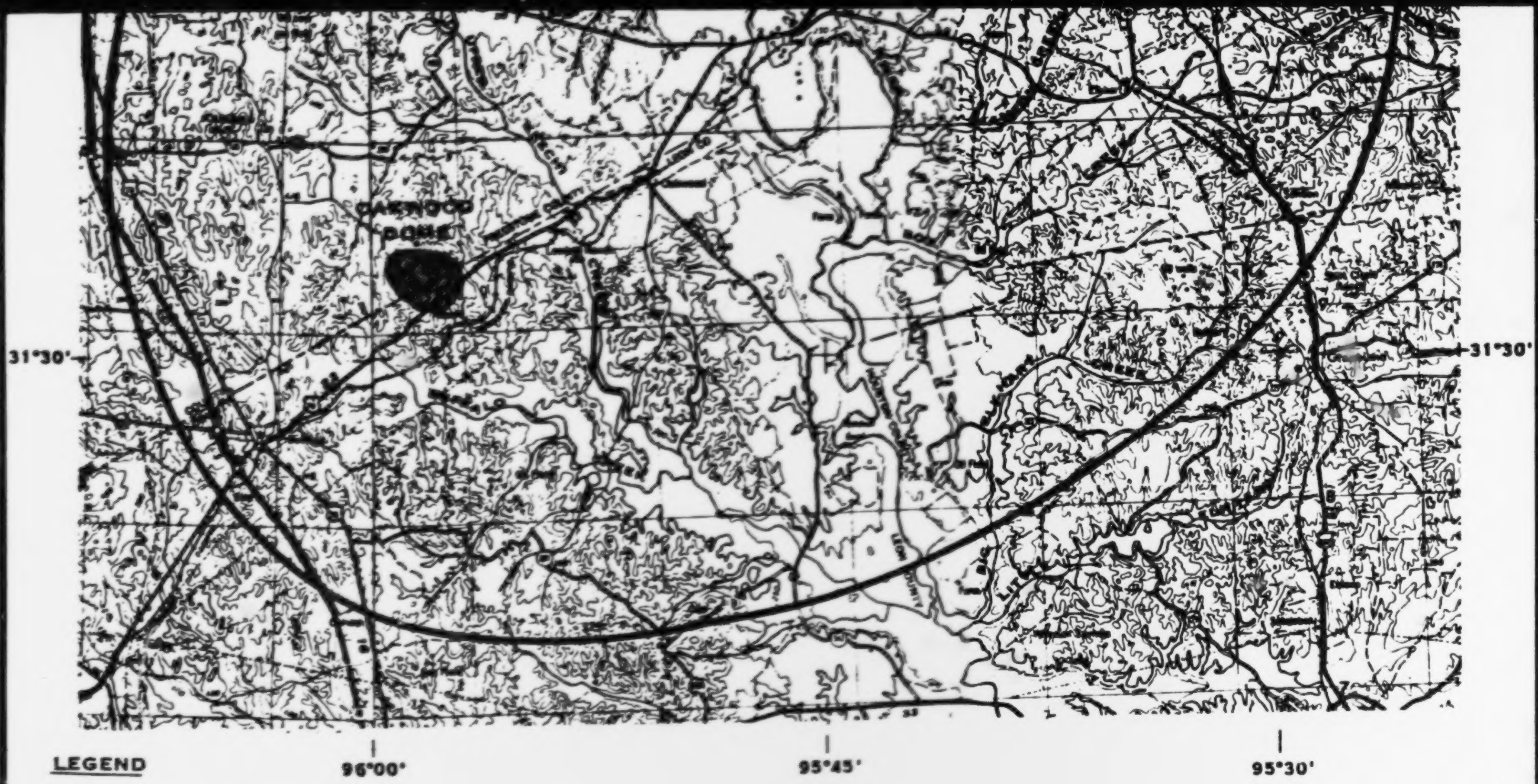
HENDERSON COUNTY
ANDERSON COUNTY
CATFISH CREEK
FREESTONE COUNTY
ANDERSON COUNTY
PALESTINE DOME
TRINITY

4A BEST DOCUMENT AVAILABLE



LEGEND

PRIMARY ROADS

45 75 19 ROUTE MARKERS, U.S., STATE

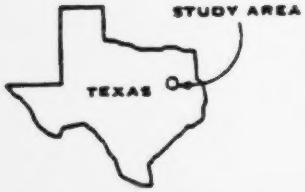
RAILROAD

SALT DOME

5 0 5 MILES

8 4 0 8 KILOMETERS

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL



BASE FROM U.S. GEOLOGICAL SURVEY
1: 62,500 QUADRANGLES.

PREPARED GLI DATE 2/15/80
REVISED GHF DATE 11/9/81
REVISED DATE
APPROVED DATE 5/15/80

T-1063-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

TOPOGRAPHIC MAP

JOB NO. MV9600

FIGURE 6-2

FIGURE 6-2

have dominated the economy of the mineral resource development industry. In addition, sand, gravel, and building stone are produced in substantial quantities. As demand increases for energy products, lignite mining may ultimately be developed commercially within the study area.

6.2 GEOLOGY OF THE EAST TEXAS STUDY AREA

Both preexisting and newly developed data were utilized to characterize the physiography, geomorphology, stratigraphy, structure, geologic history, seismicity, and mineral resources of the East Texas Study Area. By addressing these aspects of the geology, a fundamental understanding of the study area within the regional geologic framework evolved, including the near-dome and supradomal relationships.

The wide range of techniques and data sources used in the Area Characterization study had been described in detail in Section 2.1 (Volume I). The types of sources of the basic data for this study are:

(1) Oil, gas, and water wells (Figure 6-3)

(2) Seismic reflection surveys (Figure 6-3)

(3) Remote sensing (satellite and low-level imagery) (Figure 6-4)

(4) Field geologic mapping

(5) Gravity data.

6.2.1 PHYSIOGRAPHY AND GEOMORPHOLOGY: The East Texas Study Area lies entirely within the Rolling Hills and Prairie Physiographic

Subprovince of the East Texas Timberlands, corresponding to the outcrop of the Paleocene-Eocene Claiborne and Wilcox Groups (Fisher, 1965). Natural vegetation is dominantly oak and pine developed on sandy hills.

The study area is located within the drainage basins of the Trinity and Neches Rivers (Figure 6-5). Approximately 70 percent of the tributaries of the Trinity and Neches are intermittent streams, although most become perennial as their courses approach the major rivers. The drainage typically exhibits a dendritic pattern. However, in some areas of southern Anderson County an incipient trellis pattern occurs and may be controlled by geologic structures. Drainage density analysis determined that generally throughout the study area there is 13.5 km (8.4 mi) of drainage per square mile. The drainage density in the vicinity of salt domes in the East Texas Basin varies from 10.4 to 16.9 km (6.5 to 10.5 mi) per square mile (Kreitler, 1978).

Surface elevations range from 61 to 76 meters (200 to 250 ft) above sea level on the flood plain of the Trinity River and average about 137 meters (450 ft) elsewhere in the gently rolling topography which characterizes most of the terrain (Figure 6-2). The elevation ranges by counties are:

County	Elevation Range (ft above MSL)*
Anderson	200 - 650
Freestone	200 - 550
Houston	200 - 550
Leon	200 - 550

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*To convert to meters, multiply by 0.3048.

7

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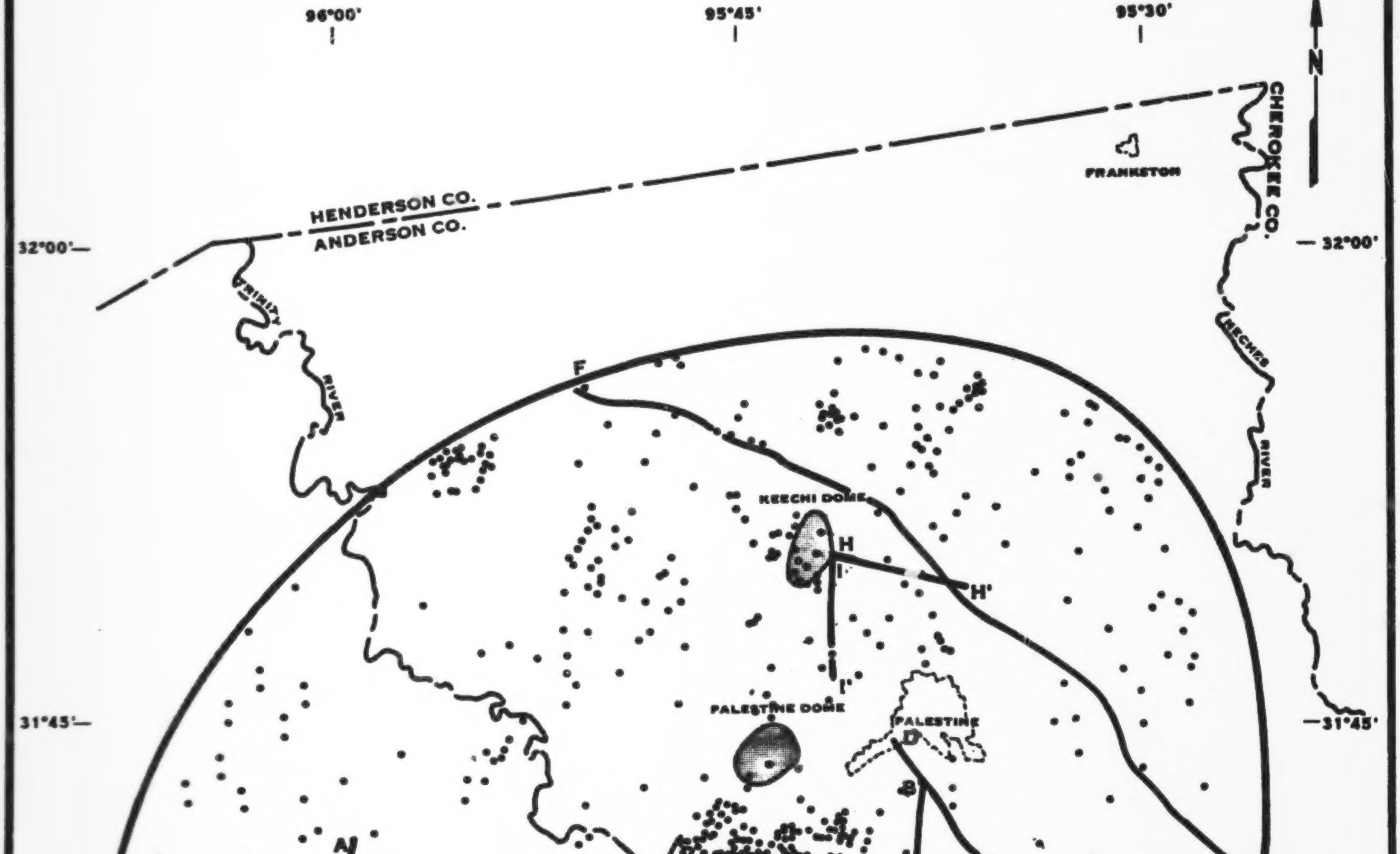
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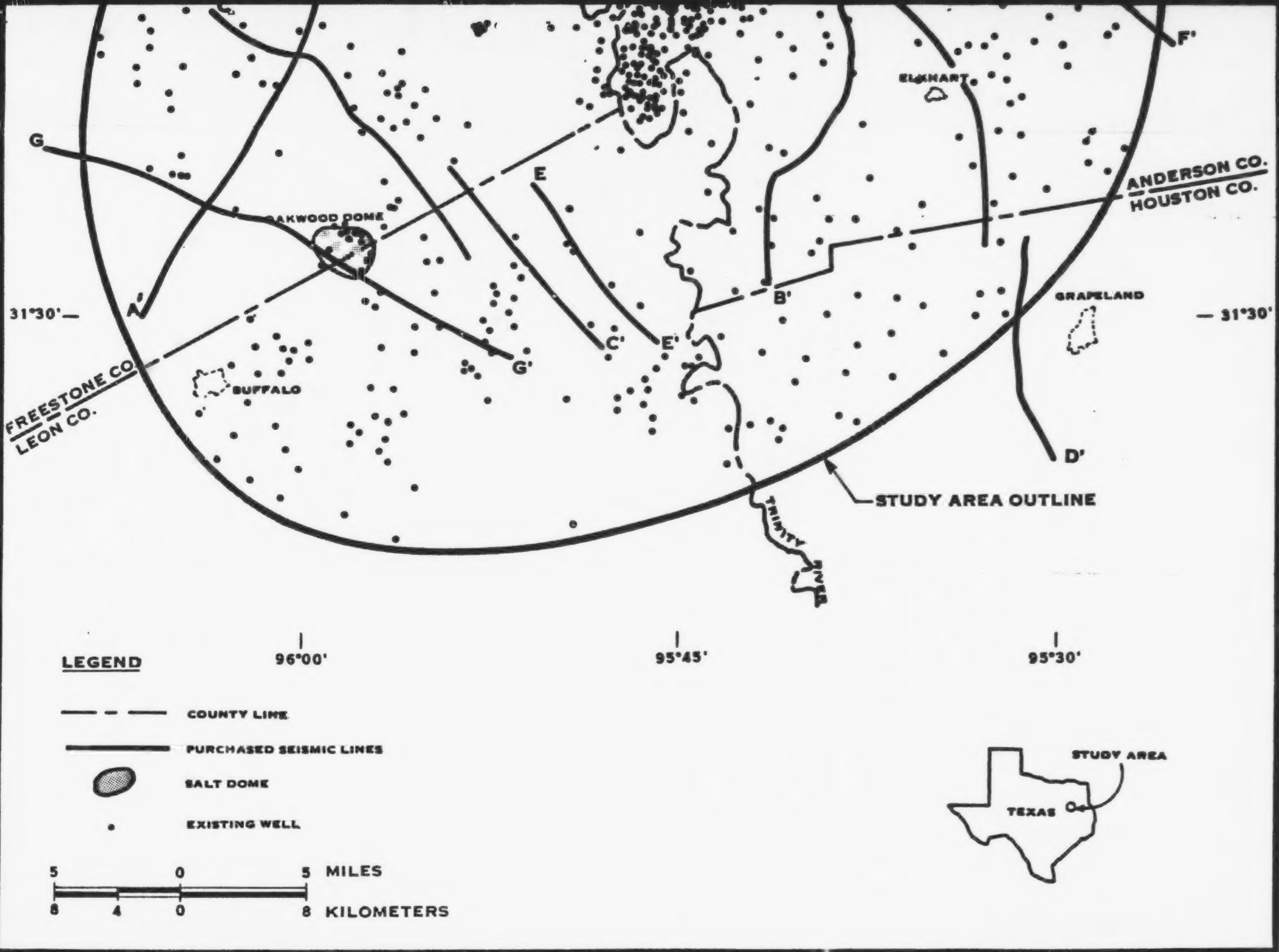
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
32°00'
32°00'
TRINITY RIVER
NECHES RIVER
F
KEECHI DOME
H
I
H'
I'
PALESTINE DOME
PALESTINE
31°45'
31°45'
D
B
A
C
F'
ELKHART


G
E
F'
ELKHART
OAKWOOD DOME
ANDERSON CO.
HOUSTON CO.
A'
B'
C'
E'
G'
D'
31°30'
31°30'
GRAPELAND
FREESTONE CO.
LEON CO.
BUFFALO
STUDY AREA OUTLINE
TRINITY RIVER
96°00'
95°45'
95°30'
LEGEND
COUNTY LINE
PURCHASED SEISMIC LINES
SALT DOME
EXISTING WELL
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS

PREPARED [illegible] DATE 2/-/80
REVISED GHF DATE 11/9/81
REVISED ______ DATE ______
APPROVED ______ DATE 6/15/80

T-1060-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA . GEORGIA

EAST TEXAS STUDY AREA

LOCATION OF WELLS AND
SEISMIC REFLECTION LINES

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FIGURE 6-3

FIGURE 6-3

7A

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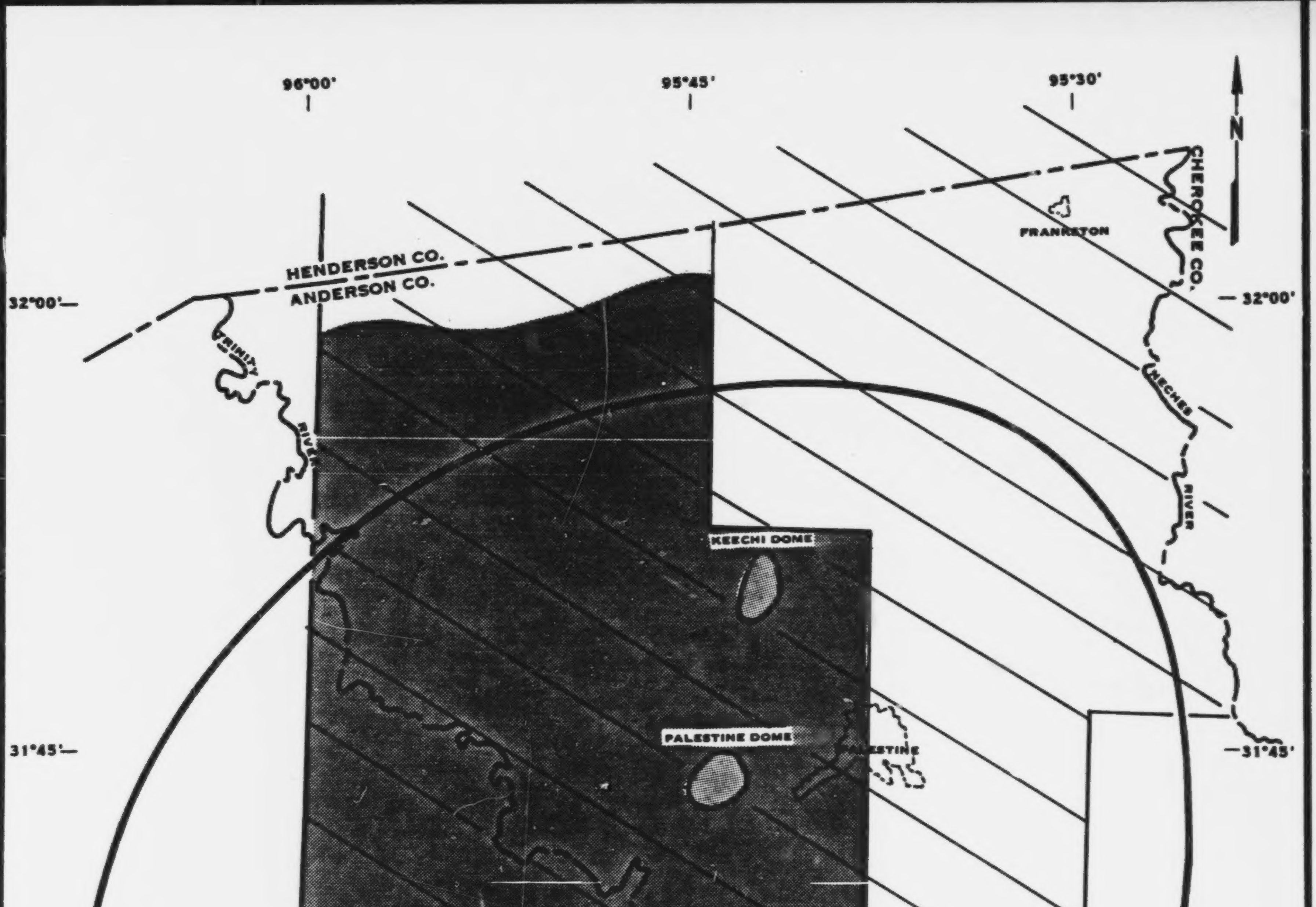
B


96°00'
95°45'
95°30'
N
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
32°00'
32°00'
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
31°45'
31°45'
ELKHART

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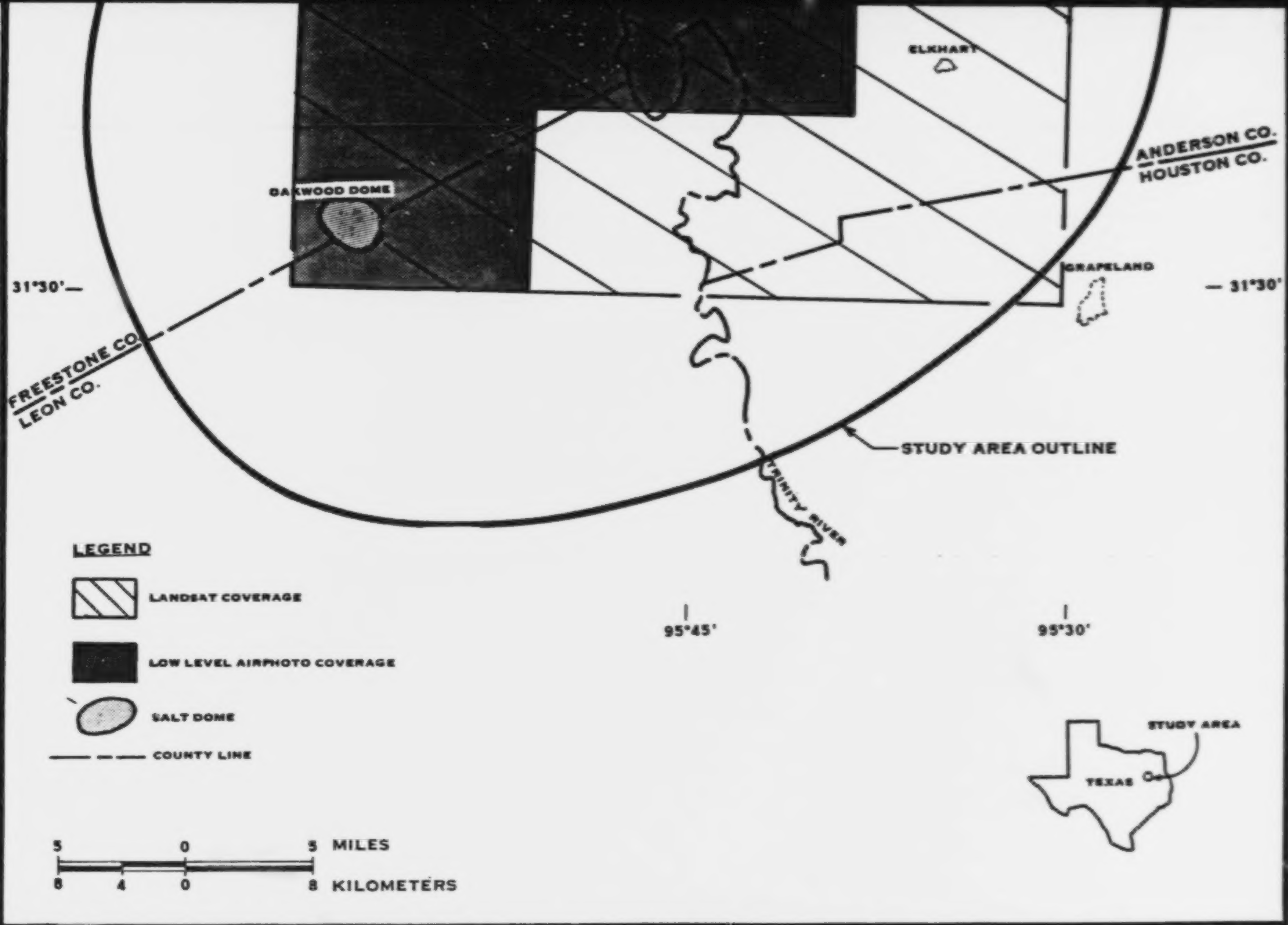
8A

FIGURE 6-4


ELKHART
ANDERSON CO.
HOUSTON CO.
OAKWOOD DOME
GRAPELAND
31°30'
31°30'
FREESTONE CO.
LEON CO.
STUDY AREA OUTLINE
TRINITY RIVER
95°45'
95°30'
LEGEND
LANDSAT COVERAGE
LOW LEVEL AIRPHOTO COVERAGE
SALT DOME
COUNTY LINE
STUDY AREA
TEXAS
5 0 5 MILES
8 4 0 8 KILOMETERS

PREPARED [illegible] DATE [illegible]
REVISED GHF DATE 11/9/81
REVISED ____ DATE ____
APPROVED DATE [illegible]

T-1061-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA . GEORGIA

EAST TEXAS STUDY AREA
LANDSAT AND LOWLEVEL
IMAGERY COVERAGE

JOB NO. MV9600

FIGURE 6-4

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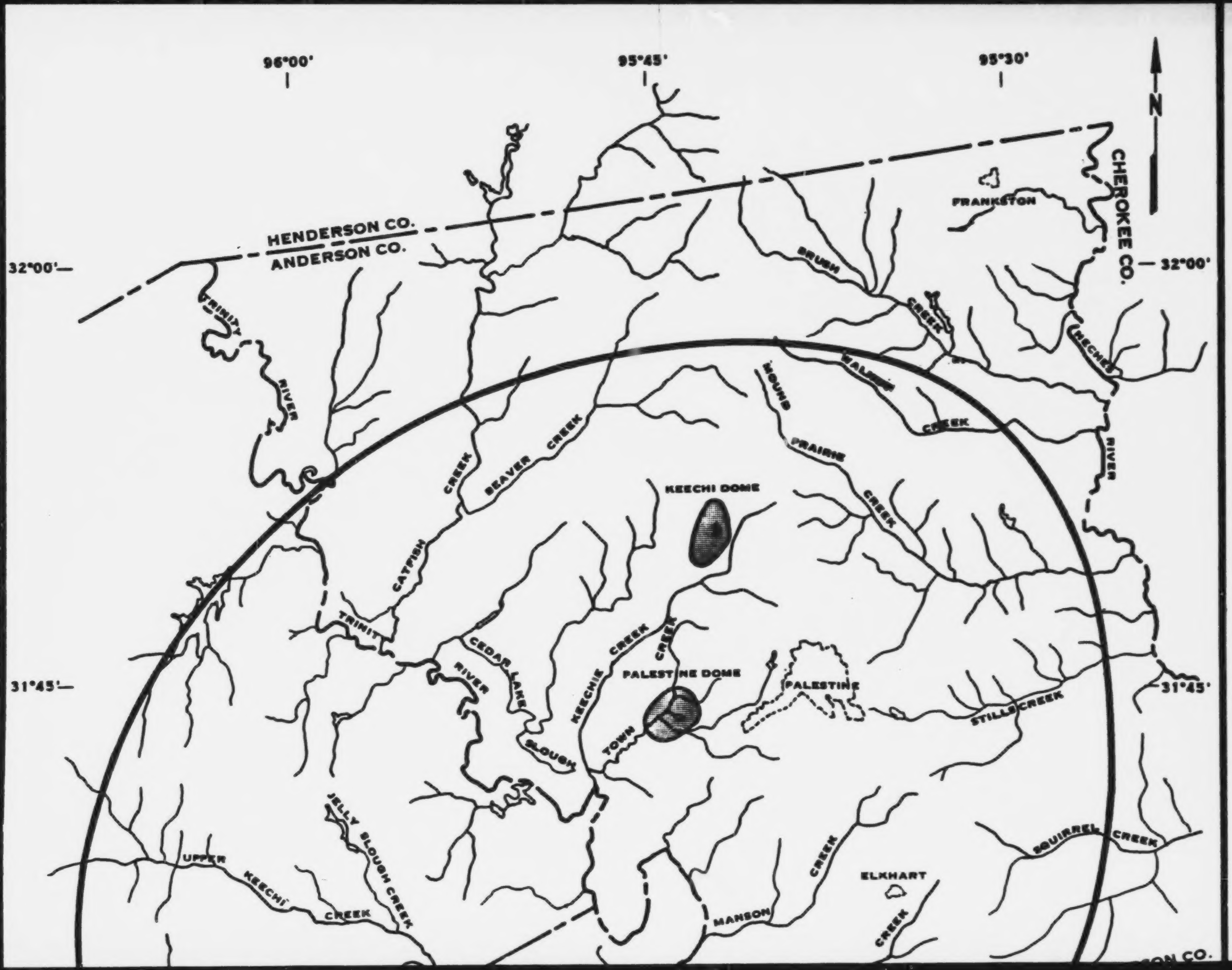
96°00'
95°45'
95°30'
N
32°00'
32°00'
31°45'
31°45'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
TRINITY RIVER
BRUSH CREEK
NECHES RIVER
MOUND PRAIRIE CREEK
CREEK
BEAVER CREEK
CATFISH CREEK
KEECHI DOME
TRINITY RIVER
CEDAR LAKE SLOUGH
KEECHIE CREEK
TOWN CREEK
PALESTINE DOME
PALESTINE
STILLS CREEK
SQUIRREL CREEK
ELKHART
MANSON CREEK
CREEK
UPPER KEECHI CREEK
JELLY SLOUGH CREEK
SON CO.

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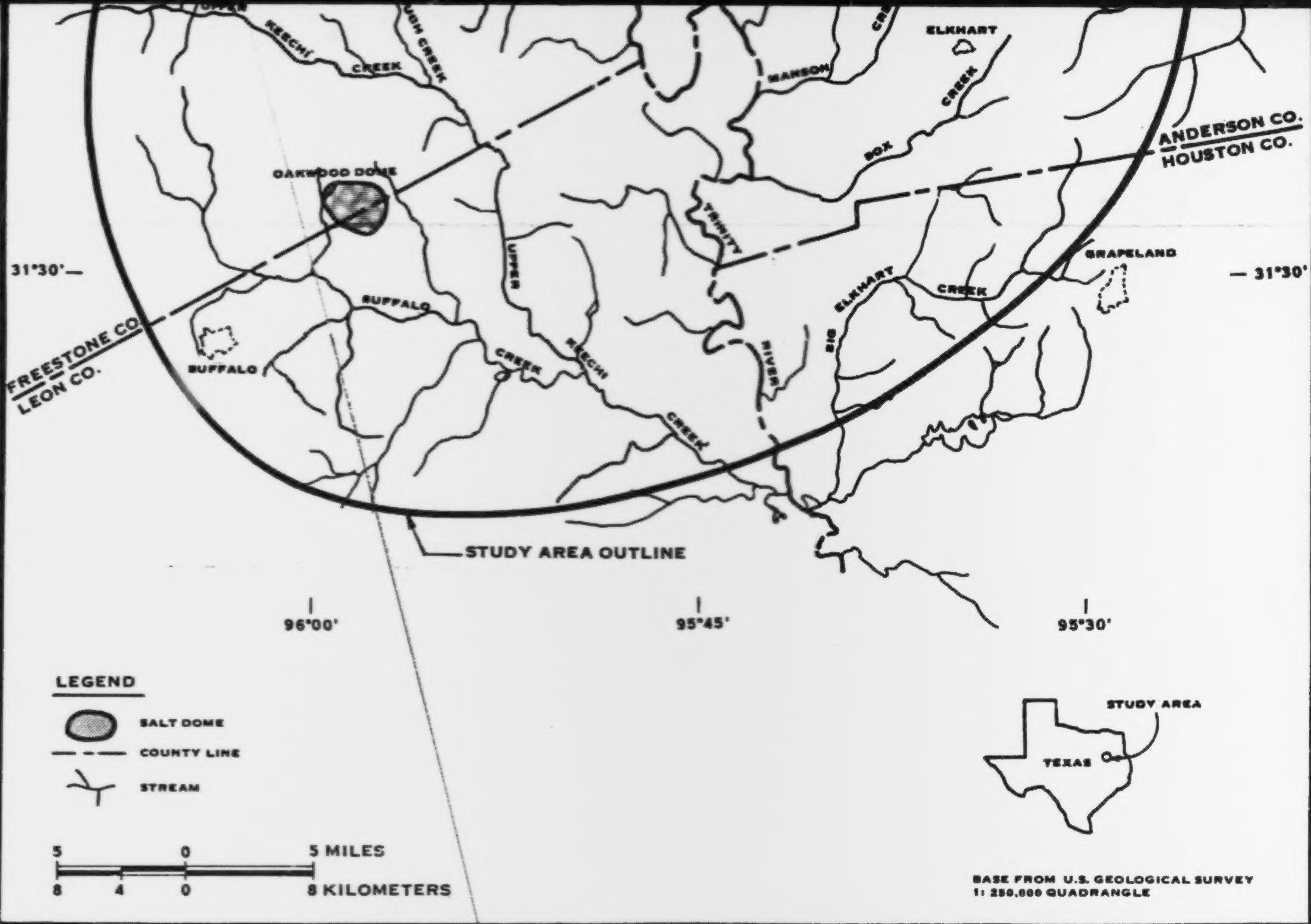
UPPER KEECHI CREEK
LOST CREEK
CREEK
ELKHART
MANSON
BOX CREEK
ANDERSON CO.
HOUSTON CO.
OAKWOOD DOME
TRINITY
31°30'
GRAPELAND
31°30'
BUFFALO
UPPER
BIG ELKHART CREEK
FREESTONE CO.
LEON CO.
BUFFALO
CREEK
KEECHI
RIVER
CREEK
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
SALT DOME
COUNTY LINE
STREAM
5
0
5 MILES
8
4
0
8 KILOMETERS
STUDY AREA
TEXAS
BASE FROM U.S. GEOLOGICAL SURVEY
1: 250,000 QUADRANGLE

FIGURE 6-5

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REVISED	GHF	DATE	11/9/81
REVISED		DATE	
APPROVED	[illegible]	DATE	[illegible]

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NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

MAJOR DRAINAGE NETWORK

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FIGURE 6-5

The lower elevations are typical of the outcrop of Quaternary deposits near the Trinity River. The higher elevations, however, generally correspond to the outcrop of Paleocene-Eocene in upland areas, away from major drainage courses. This contrast establishes a distinctive topographic basis for subdividing the study area. The areas adjacent to the Trinity River, within its active flood plain, are the only flat surfaces within the study area (Figures 6-2 and 6-6). The width of the flood plain, which is composed of Recent sands and clays averaging 6 meters (20 ft) in thickness, varies from about 3 to 8 km (2 to 5 mi).

Small oxbow lakes and swampy areas or peat bogs are commonly present within the modern flood plain of the Trinity River. Throughout its course in the study area, the Trinity River channel is incised into an older flood plain, and still older Tertiary deposits which typically form steep slopes up to 9 meters (30 ft) high along the river channel.

Quaternary Pleistocene terraces that border the Trinity River flood plain are remnants of former flood plain surfaces at various elevations (Figure 6-6). These alluvial terrace deposits, composed mainly of sand and some gravel, lie upon Tertiary sediments and occur sporadically along either side of the river.

There is no conclusive evidence to determine how far inland the eustatic effects of the Quaternary glaciations were felt. Nevertheless, it is reasonable to assume that fluctuations in sea level during Quaternary glacial and interglacial stages caused corresponding changes in the base levels which controlled stream erosion or alluviation. As seas receded during the first glacial stage, rivers cut valleys and then filled them during the transgression of the following interglacial period. The next glacial stage was again marked by a drop in sea level; the rivers again formed valleys in the earlier deposits and then filled them. The alternation of stream cutting and filling progressed through at least four successive cycles of glaciation. In some areas within the study area, such as along U.S. 79, connecting the towns of Oakwood and Palestine, the terrace levels exhibit in valley profile a stair-step arrangement on both borders of the modern Trinity River flood plain.

In the upland area away from the Trinity River, various landforms typical of the underlying Tertiary Paleocene-Eocene sediments are recognized. The distribution of landforms is partly controlled by major regional structural elements of the East Texas Basin, as well as by more localized structural features such as salt domes and faults. The geomorphic characteristics of the East Texas Basin and those of the Lower Gulf Coastal Basin are merged within the study area. The geomorphology of the study area is further modified by displacement and adjustment of beds and related land forms within the Mt. Enterprise Fault Zone (Figure 6-7).

The portion of the study area west of the Trinity River features topography controlled by the outcrop belts of Wilcox and Claiborne sediments, striking northeast-southwest and dipping toward the southeast. The northern half of the study area, which is east of the Trinity River, encompasses geomorphic characteristics similar to those of the eastern part, with a series of

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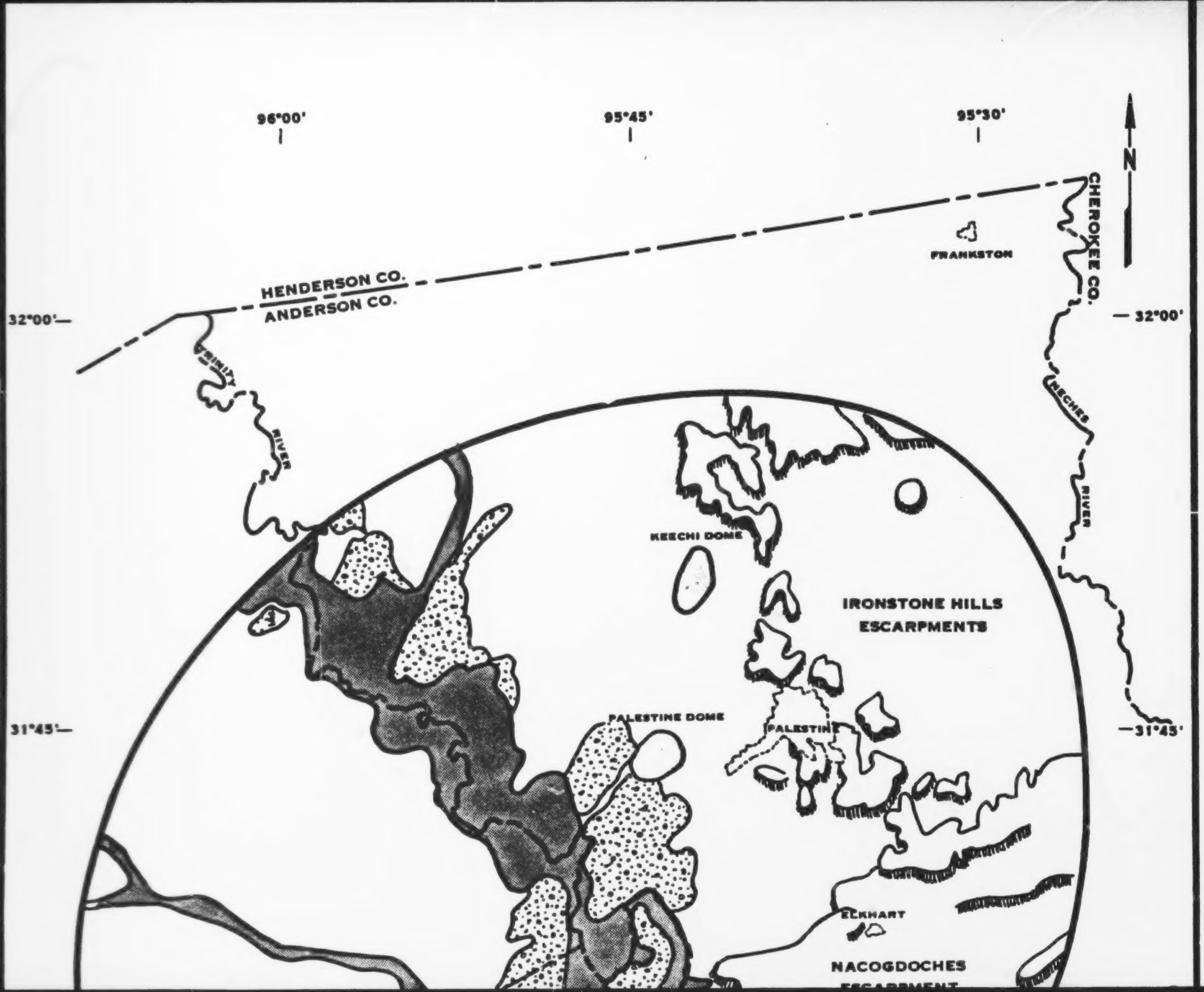
96°00'
95°45'
95°30'
N
CHEROKEE CO.
FRANKSTON
HENDERSON CO.
ANDERSON CO.
32°00'
32°00'
TRINITY
RIVER
NECHES
RIVER
KEECHI DOME
IRONSTONE HILLS
ESCARPMENTS
PALESTINE DOME
PALESTINE
31°45'
31°45'
ELKHART
NACOGDOCHES
ESCARPMENT

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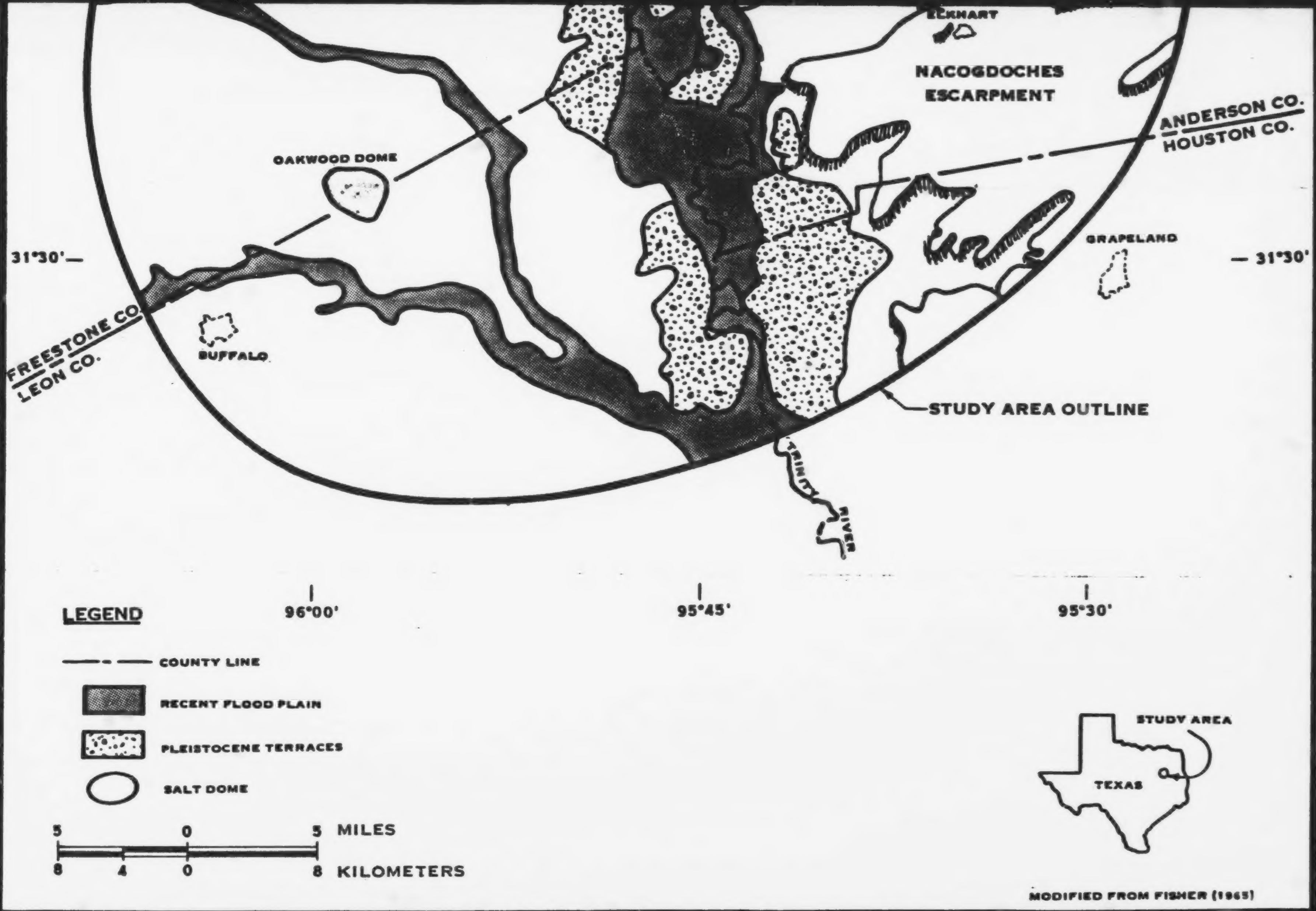
ECKHART
NACOGDOCHES ESCARPMENT
ANDERSON CO.
HOUSTON CO.
OAKWOOD DOME
GRAPELAND
31°30'
31°30'
FREESTONE CO.
LEON CO.
BUFFALO
STUDY AREA OUTLINE
TRINITY RIVER
96°00'
95°45'
95°30'
LEGEND
COUNTY LINE
RECENT FLOOD PLAIN
PLEISTOCENE TERRACES
SALT DOME
5
0
5
MILES
8
4
0
8
KILOMETERS
STUDY AREA
TEXAS

MODIFIED FROM FISHER (1965)

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REVISED DATE
APPROVED DATE 8/15/80

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

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EAST TEXAS STUDY AREA

PHYSIOGRAPHIC FEATURES MAP

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FIGURE 6-6

FIGURE 6-6

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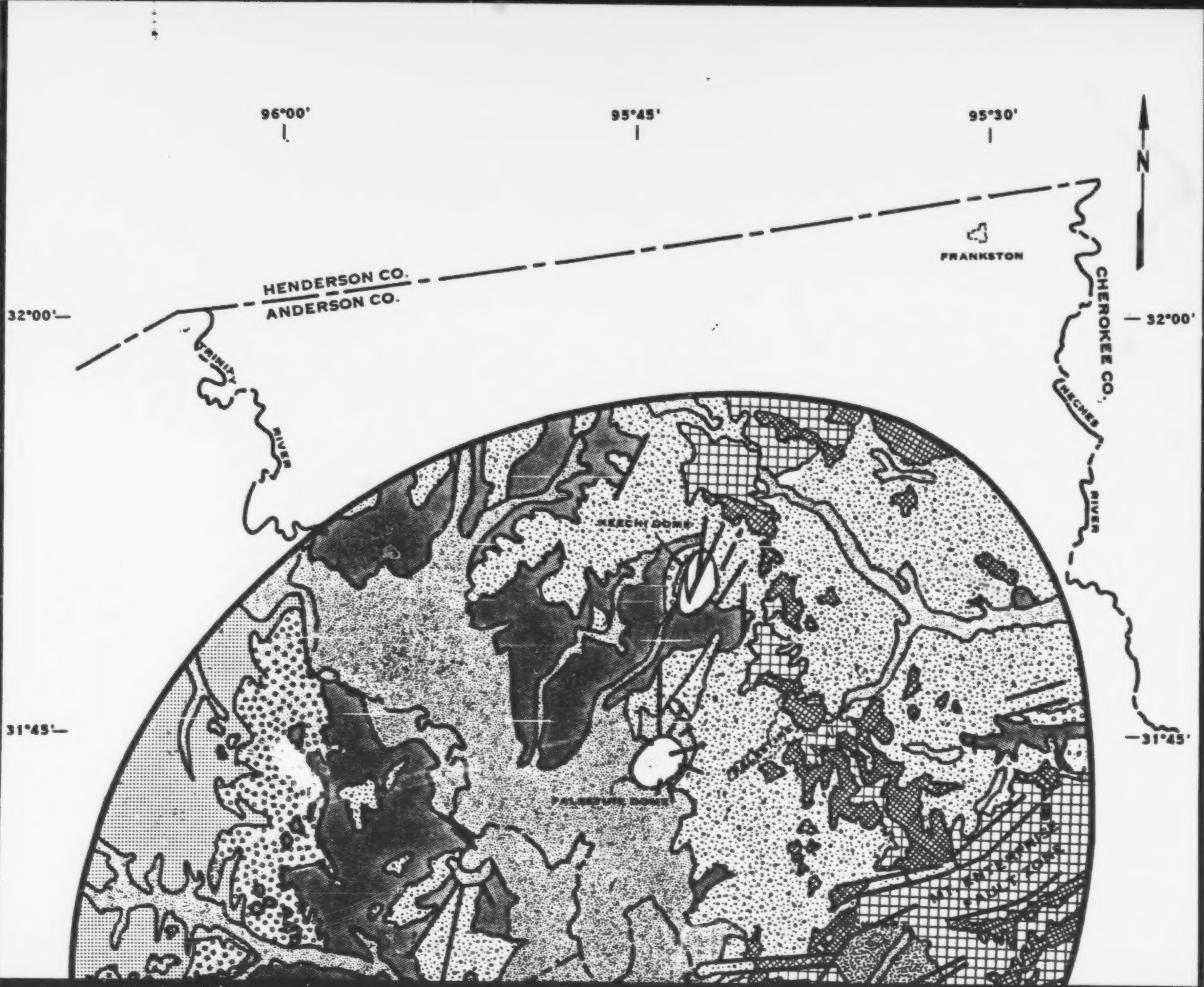
96°00'
95°45'
95°30'
N
32°00'
32°00'
31°45'
31°45'
HENDERSON CO.
ANDERSON CO.
FRANKSTON
CHEROKEE CO.
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME

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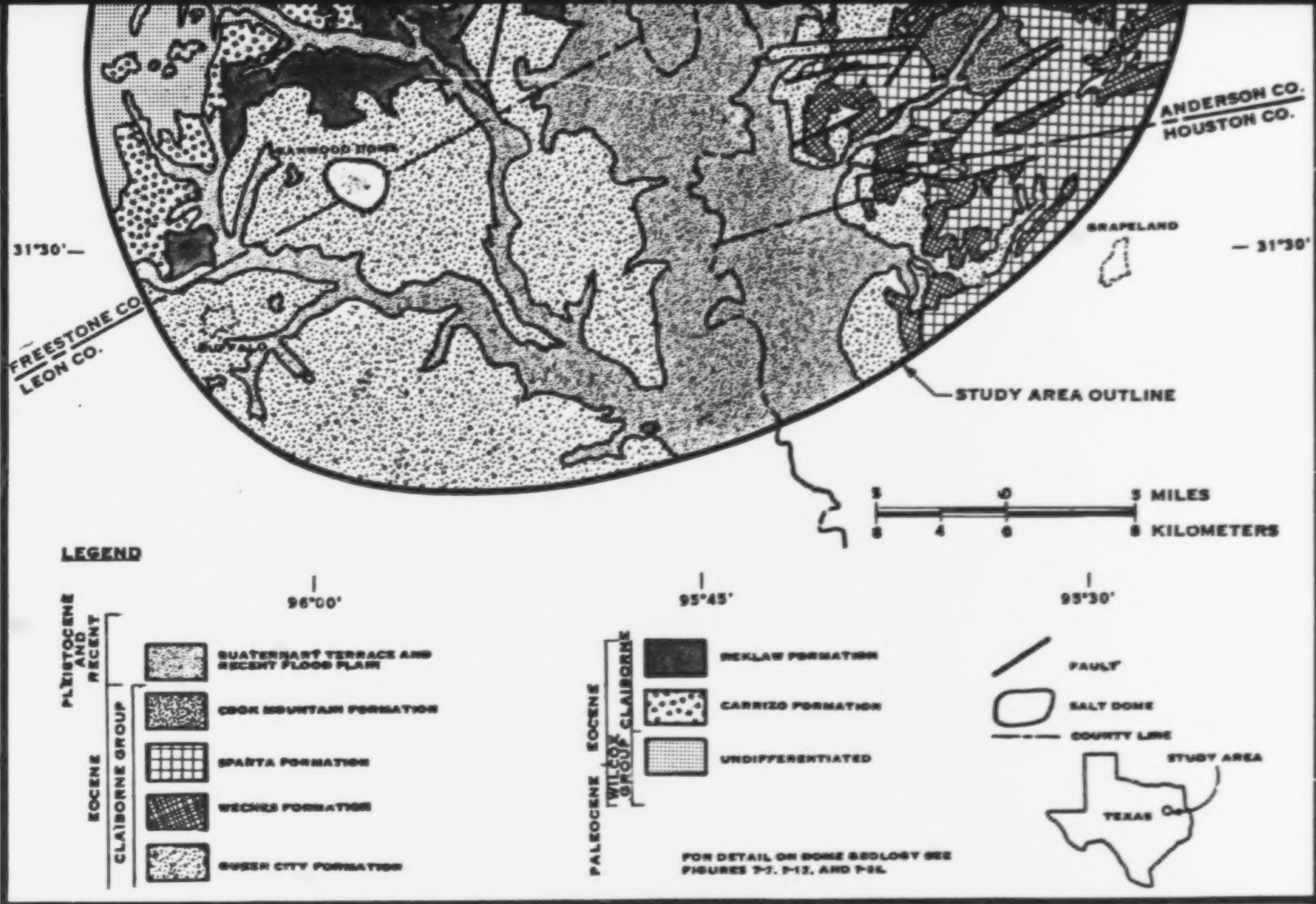
KEECHI DOME
31°30'
31°30'
ANDERSON CO.
HOUSTON CO.
GRAPELAND
FREESTONE CO.
LEON CO.
BUFFALO
STUDY AREA OUTLINE
5 0 5 MILES
8 4 0 8 KILOMETERS
LEGEND
96°00'
95°45'
95°30'
PLEISTOCENE AND RECENT
EOCENE
CLAIBORNE GROUP
QUATERNARY TERRACE AND RECENT FLOOD PLAIN
COOK MOUNTAIN FORMATION
SPARTA FORMATION
WECHES FORMATION
QUEEN CITY FORMATION
PALEOCENE EOCENE
WILCOX GROUP
CLAIBORNE
REKLAW FORMATION
CARRIZO FORMATION
UNDIFFERENTIATED
FAULT
SALT DOME
COUNTY LINE
STUDY AREA
TEXAS
FOR DETAIL ON DOME GEOLOGY SEE FIGURES 7-7, 7-12, AND 7-26.

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REVISED *GHF* DATE *11/9/81*
REVISED ______ DATE ______
APPROVED *[illegible]* DATE *8/15/80*

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GEOLOGIC EVALUATION GULF COAST SALT DOMES

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EAST TEXAS STUDY AREA

GEOLOGIC MAP

JOB NO. MV9600

FIGURE 6-7

FIGURE 6-7

flat, low-relief hills which corresponds to outliers of Upper Claiborne sediments trending north-south through the city of Palestine. The southern portion of the study area east of the Trinity River reflects alternating sequences of Upper Claiborne sediments striking eastward, controlled by graben and horst segments of the Mt. Enterprise Fault Zone.

Within the study area, the alternation of relatively soft sedimentary rocks and more resistant beds and the general gulfward dip of the outcropping units have produced cuestas with north-facing escarpments. In the eastern portion of the study area, the Ironstone Hills and the Nacogdoches Escarpments (Figure 6-6) are capped by indurated, ferruginous sediments of the Weches Formation in the Claiborne Group (Fisher, 1965). The Nacogdoches Escarpment, located along the southern portion of the study area, is locally disrupted by faulting associated with the Mt. Enterprise Fault Zone. The cuestal escarpments are often dissected into low hills, with relief up to 61 meters (200 ft). Streams are commonly deflected at the base of the more resistant escarpments. Less pronounced and less continuous escarpments locally occur at lower elevations along the outcrop of the Reklaw Formation because of resistant, intraformational ironstone ledges.

6.2.2 STRATIGRAPHY: The Mesozoic and Cenozoic sedimentary rocks in the study area record a sequence of transgressions and regressions, developing recurrent transitions from fluvial to marine depositional systems throughout the East Texas Basin.

The stratigraphy of the study area, consisting of a succession of depositional sequences, is typical of the East Texas

Basin (Table 6-1). In general, each sequence begins with a lower, dominantly fluvio-deltaic unit of sandstones and shales followed (overlain) by shelf carbonates and shales. An accumulation of up to 5,791 meters (19,000 ft) of sediments was deposited during the following six depositional sequences (Kreitler and others, 1980):

(1) Louann Salt
(2) Norphlet-Bossier
(3) Schuler-Upper Glen Rose
(4) Paluxy-Maness
(5) Woodbine-Midway
(6) Wilcox-Claiborne Clastics (partial).

The first sequence consists entirely of evaporites, and the sixth sequence is represented only by a regressive phase. The sources of most of the detrital sediments were the positive areas lying outside of the East Texas Basin to the west and the north.

A composite electric well log presented in Figure 6-8 generally depicts the sedimentary section found within the study area. The log shows typical electric responses (signatures) of the subsurface units used in the stratigraphic correlation.

This section, which briefly describes the stratigraphy of the study area by successive groups of depositionally related formations, is largely taken from the literature (Nichols, 1964 and Nichols and others, 1968). Seismic and well data (Figure 6-3 and Table A-4.1 in the Appendix) have been utilized to describe the lateral development of the stratigraphic sequence at depth. Detailed information on the age relationships and the depositional relationships is presented in Table 6-1.

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TABLE 6-1
SUMMARY OF EAST TEXAS STUDY AREA STRATIGRAPHY

				FORMATION	AGE MYBP	THICKNESS FEET	LITHOLOGIC DESCRIPTION
CENOZOIC ERA	QUATERNARY			RECENT PLEISTOCENE	1.8	LESS THAN 60'	UNCONSOLIDATED SAND, SILT AND CLAY, SOME GRAVEL
	TERTIARY SYSTEM	EOCENE SERIES	CLAIBORNE GROUP	COOK MOUNTAIN		0' TO 370'	GLAUCONITIC SAND INTERBEDDED WITH SILT AND CLAY
				SPARTA		0' TO 250'	GLAUCONITIC CLAY AND SILT
				WECHES		0' TO 75'	GLAUCONITIC CLAY AND SAND
				QUEEN CITY		0' TO 400'	UNCONSOLIDATED, MEDIUM TO FINE GRAINED SAND INTERBEDDED WITH SILT AND CLAY
				REKLAW		0' TO 150'	UPPER PORTION IS SILTY, CARBONACEOUS CLAY; LOWER PORTION IS SILTY
				CARRIZO	50	0' TO 200'	UPPER PORTION IS SILTY SAND AND CLAY. LOWER PORTION IS MASSIVE, UNCONSOLIDATED, MEDIUM TO FINE SAND
		PALEOCENE SERIES	WILCOX GROUP	UNDIFFERENTIATED	58	0' TO 2800'	VERY FINE GRAINED SILTS TO POORLY CONSOLIDATED SANDSTONES BEDDED LIGNITE COMMON
			MIDWAY GROUP	UNDIFFERENTIATED	65	0-900	PREDOMINANTLY MICACEOUS, OCCASIONALLY CALCAREOUS SHALE WITH SOME THIN BEDS OF VERY FINE GRAINED GLAUCONITIC SANDSTONES
OIC ERA	ETACEOUS SYSTEM	GULFIAN SERIES	NAVARRO GROUP	UPPER NAVARRO		90' TO 260'	MICROFOSSILIFEROUS, MICACEOUS, SILTY SHALE INTERBEDDED WITH MARL, SILTSTONE
				NACATOCH		0' TO 80'	MICROFOSSILIFEROUS, CALCAREOUS SANDY MARL
				LOWER NAVARRO		300' TO 650'	MICROFOSSILIFEROUS, MICACEOUS, SILTY SHALE INTERBEDDED WITH MARL, SILTSTONE
			TAYLOR GROUP	UPPER TAYLOR		100' TO 400'	MICROFOSSILIFEROUS MARL AND FISSILE, SLIGHTLY CALCAREOUS SHALE
				PECAN GAP		80' TO 250'	VERY MICROFOSSILIFEROUS CHALK
				WOLF CITY SAND		30' TO 120'	THINLY BEDDED, ARGILLACEOUS, VERY FINE GRAINED, GLAUCONITIC SANDSTONE
				LOWER TAYLOR		250' TO 570'	MICACEOUS, GLAUCONITIC, CALCAREOUS TO NON-CALCAREOUS SHALE
			AUSTIN GROUP	GOBER		15' TO 50'	ARGILLACEOUS, FOSSILIFEROUS, CHALKY LIMESTONE
				MIDDLE AUSTIN		350' TO 500'	THINLY BEDDED, FISSILE, MICACEOUS CLAY AND MARL WITH LOCAL THIN GLAUCONITIC SANDSTONES
				ECTOR		270' TO 370'	MASSIVE CHALK WITH INTERBEDDED CALCAREOUS SHALE
			EAGLE FORD GROUP	SUB-CLARKSVILLE SAND		10' TO 30'	THINLY BEDDED, FINE GRAINED, ARGILLACEOUS, GLAUCONITIC, CALCAREOUS SANDSTONE
				EAGLE FORD		150 TO 350'	LAMINATED, MICACEOUS, CARBONACEOUS SHALE; CALCAREOUS IN PART
			WOOD-BINE GROUP	UNDIFFERENTIATED	100	250' TO 500'	VERY FINE TO MEDIUM GRAINED, WELL SORTED, FRIABLE, CALCAREOUS TO NON-CALCAREOUS SANDSTONES INTERBEDDED WITH WAXY SHALES AND MUDSTONES
			HITA GROUP	MANESS		0' TO 170'	FAINTLY LAMINATED, FOSSILFEROUS SHALE
				BUDA		100' TO 200'	DENSE, MICROSPHERULITIC, SLIGHTLY FOSSILIFEROUS LIMESTONE
				GRAYSON		10' TO 100'	FISSILE, CALCAREOUS SHALE INTERBEDDED WITH DENSE, MICROCRYSTALLINE, ARGILLACEOUS LIMESTONE
			TOWN OUP	MAIN STREET		200' TO 300'	INTERBEDDED MICROSPHERULITIC, SUBLITHOGRAPHIC, DENSE LIMESTONE AND FISSILE, SLIGHTLY CALCAREOUS SHALE
				WENO-PAW PAW		60' TO 130'	
				DENTON		30' TO 70'	

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MESOZOIC	CRETACEOU	COMANCHEAN SERIES	WASHITA GROU			GRAYSON		[illegible]	MICROCRYSTALLINE, ARGILLACEOUS LIMESTONE
				GEORGETOWN SUBGROUP		MAIN STREET		200' TO 350'	INTERBEDDED MICROSPHERULITIC, SUBLITHOGRAPHIC, DENSE LIMESTONE AND FISSILE, SLIGHTLY CALCAREOUS SHALE
						WENO-PAW PAW		90' TO 130'	
						DENTON		20' TO 70'	
						FORTH WORTH		100' TO 200'	
						DUCK CREEK SHALE		80' TO 150'	
						DUCK CREEK LIMESTONE		66' TO 250'	
			FREDERICKSBURG GROUP			KIAMICHI		40' TO 120'	SHALE ALTERNATING WITH THIN LIMESTONE BEDS
						GOODLAND		200' TO 500'	DENSE, MICROCRYSTALLINE, FOSSILIFEROUS LIMESTONE INTERBEDDED WITH FISSILE SHALE
			TRINITY GROUP			PALUXY		250' TO 400'	INTERBEDDED ARGILLACEOUS SANDSTONE AND FISSILE, PYRITIC SHALE; SOME INTERBEDDED DENSE LIMESTONE
				GLEN ROSE SUBGROUP		UPPER GLEN ROSE		800' TO 1500'	INTERBEDDED SUBLITHOGRAPHIC TO MICROCRYSTALLINE LIMESTONE AND FISSILE SHALE AND ANHYDRITE STRINGERS
						FERRY LAKE		200' TO 700'	ANHYDRITE INTERBEDDED WITH SHALE AND DENSE, PELLETAL-OOLITIC LIMESTONE
					LOWER GLEN ROSE FM	RODESSA		400' TO 700'	INTERBEDDED LIMESTONE, SHALE, SANDSTONE AND ANHYDRITE
						JAMES		80' TO 120'	INTERBEDDED DENSE LIMESTONE, MICROCRYSTALLINE, ARGILLACEOUS LIMESTONE AND CALCAREOUS SHALES
						PINE ISLAND		80' TO 120'	FINELY MICACEOUS SHALE AND CLAYSTONE INTERBEDDED WITH SILTSTONE
						PETTET		100' TO 300'	DENSE MICROCRYSTALLINE FOSSILIFEROUS, LIMESTONE INTERBEDDED WITH CALCAREOUS SHALE IN UPPER PORTION, TO OOLITIC ARGILLACEOUS, FOSSILIFEROUS LIMESTONE NEAR BASE
						TRAVIS PEAK		2000' TO 3000'	INTERBEDDED SILTY SHALES AND SANDSTONES: SCATTERED CHERT AND QUARTZ PEBBLE CONGLOMERATE
	JURASSIC SYSTEM	UPPER JURASSIC	COTTON VALLEY GROUP			KNOWLES	135	0' TO 500'	MICRITIC ARGILLACEOUS, LIMESTONE WITH INTERBEDDED SANDSTONES AND SHALES
						SCHULER		600' TO 900'	FINE TO MEDIUM GRAINED SANDSTONE INTERBEDDED WITH WAXY SHALES: LOCALLY CONGLOMERATIC
						BOSSIER		700' TO 900'	INTERBEDDED WAXY SHALES AND MICROCRYSTALLINE, ARGILLACEOUS LIMESTONES
			LOUARK GROUP			GILMER		600' TO 1500'	FINE GRAINED SANDSTONE AND INTERBEDDED CONGLOMERATES: ANHYDRITE WITH HALITE, DOLOMITE THIN SHALES: DENSE MICROCRYSTALLINE LIMESTONES
						BUCKNER		300' TO 1500'	
						SMACKOVER		1000' TO 1200'	DENSE MICROCRYSTALLINE LIMESTONE: MODERATELY FOSSILIFEROUS OOLITES: POROUS TO NON-POROUS DOLOMITES
						NORPHLET		50' TO 150'	VERY FINE GRAINED, WELL SORTED, CALCAREOUS SANDSTONES INTERBEDDED WITH SILTSTONES AND CLASTIC SHALES
		LOWER JURASSIC	LOUANN GROUP AGE UNCERTAIN			LOUANN SALT		TO 3300'	NEARLY PURE HALITE WITH THIN BEDS AND INCLUSIONS OF ANHYDRITE
						WERNER			
	TRIASSIC	UPPER TRIASSIC				EAGLE MILLS			
PRE-MESOZOIC									

PREPARED		DATE	8/15/80
REVISED	GHF	DATE	11/7/81
REVISED		DATE	
APPROVED		DATE	8/15/80

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

SUMMARY OF STRATIGRAPHY

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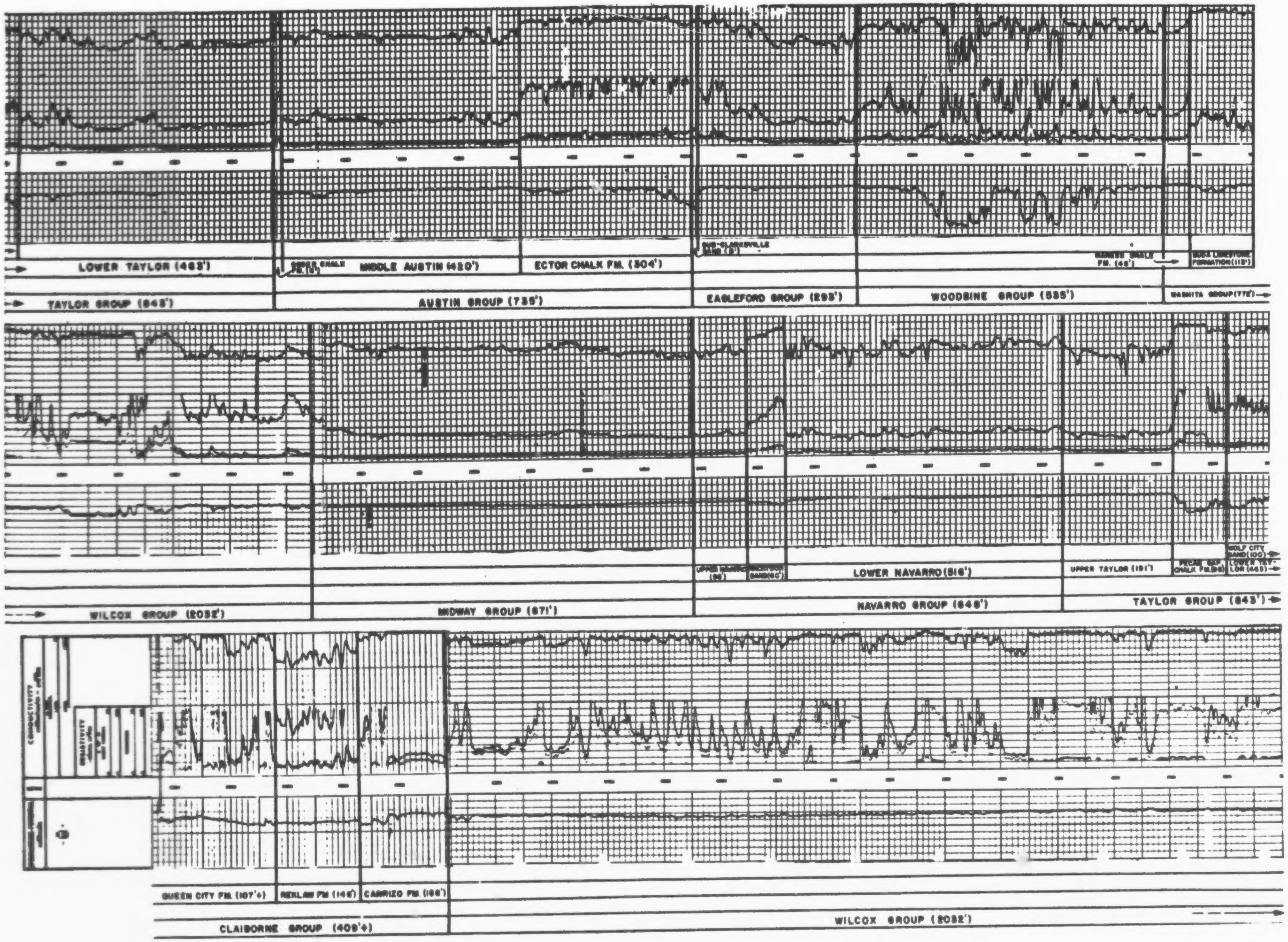
TABLE 6-1



COMPOSITE LOG FROM:

JACKSON, GUENTHER #2
BEEKAY, LEE #1
HUMBLE, #2-A RED LAKE G. U. #3

EAST TEXAS STUDY AREA
COMPOSITE GEOPHYSICAL WELL LOG

JOB NO. MV9600
(PAGE 1 OF 3)

FIGURE 5-8

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

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REVISED ______ DATE 8/15/80
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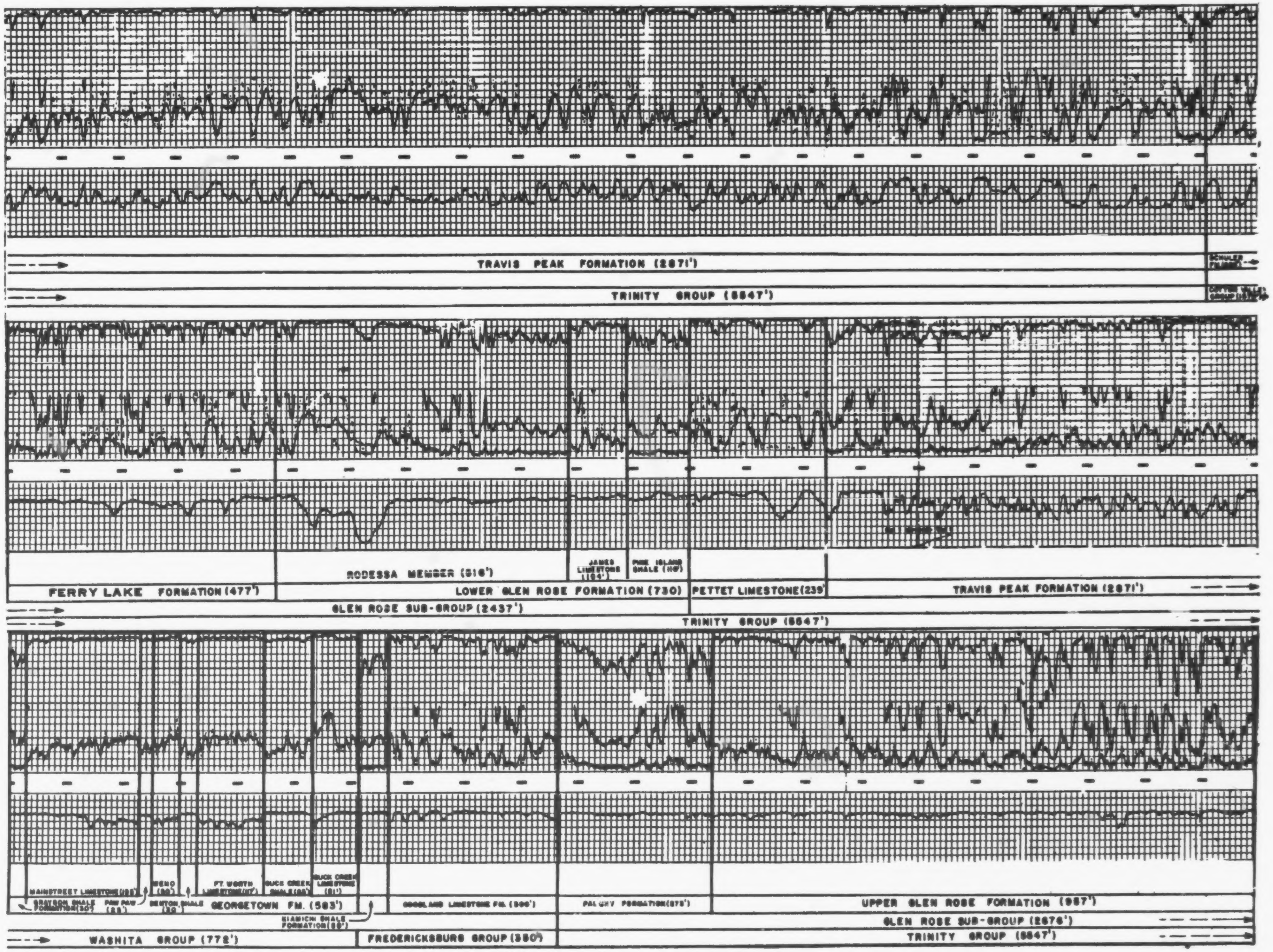

EAST TEXAS STUDY AREA
COMPOSITE GEOPHYSICAL WELL LOG

JOB NO. MV9600
(PAGE 2 OF 3)

FIGURE 6-8

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

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REVISED ______ DATE ______
APPROVED ______ DATE 2/15/80

T-1068B-0

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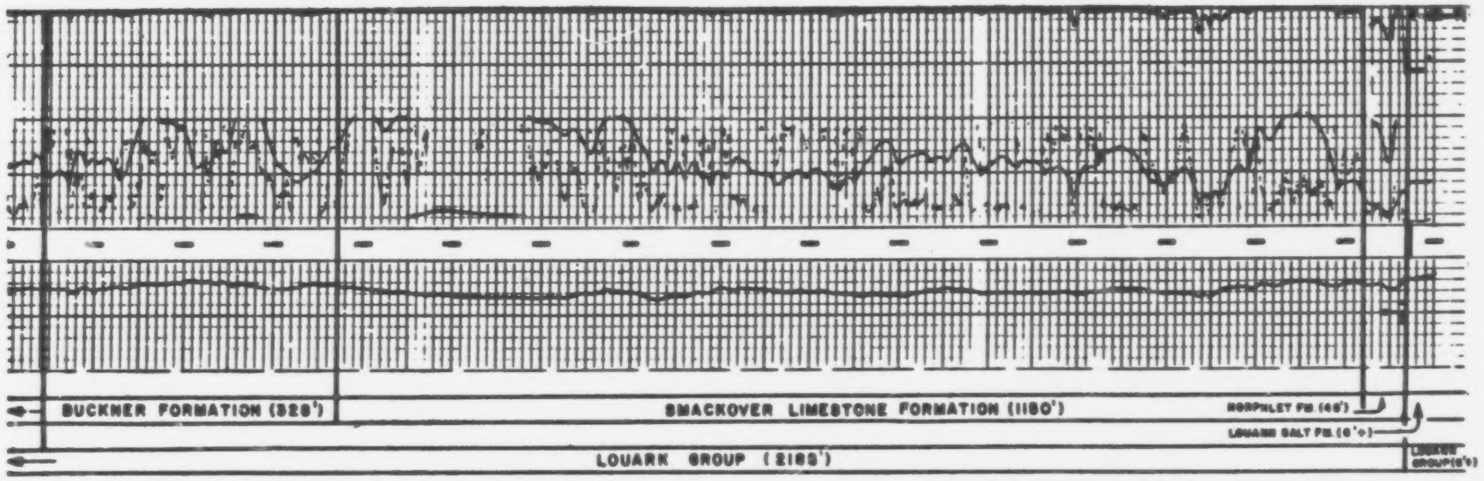
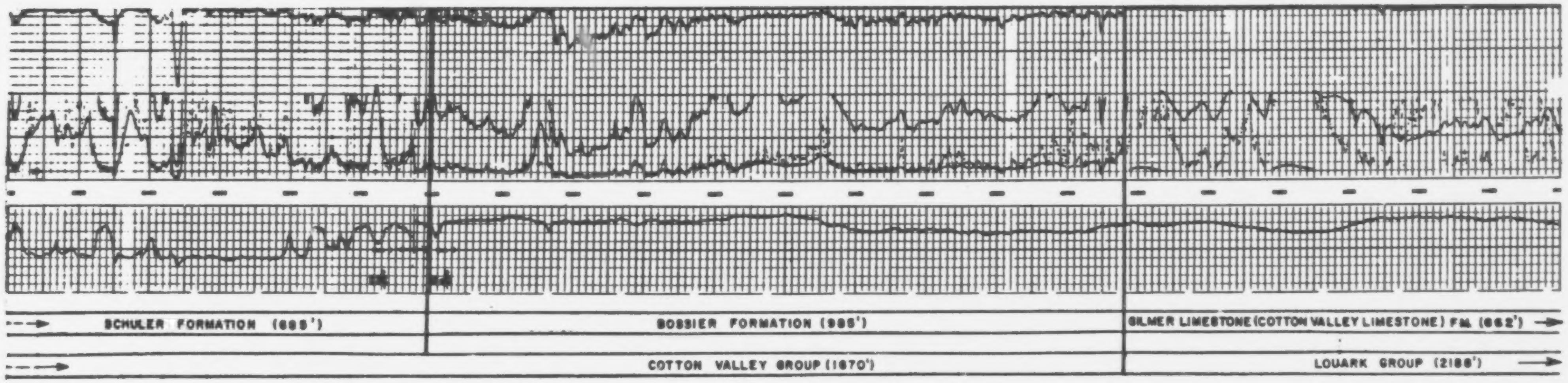
FIGURE 6-8 (Page 2 of 3)





EAST TEXAS STUDY AREA
COMPOSITE GEOPHYSICAL WELL LOG

JOB NO. MV9600
(PAGE 3 OF 3)

FIGURE 6-8

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

PREPARED ______ DATE 8/15/80
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED ______ DATE 8/15/80

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6.2.2.1 Triassic: The Triassic within the study area is represented only by Upper Triassic sediments of the Louann Group. The Louann Group, consisting of the Werner Formation and the overlying Louann Salt, unconformably overlies older units.

The age of the Louann Salt is still uncertain and it probably varies throughout the Gulf Region during its developmental history. A Jurassic or Late Triassic age is considered possible for the Louann Salt and underlying Werner Formation in the northern Gulf Region (Murray, 1961; Halbouty, 1979; Atwater, 1968). Most investigators, however, favor a Jurassic age (Imlay, 1943; McKee and others 1956; Bishop, 1967). Recent studies concerning the stratigraphy of the entire Gulf Region, including the Northeast Texas Embayment, by E.G. Anderson (1979) propose an Uppermost Triassic to Lowermost Jurassic age for the Louann Salt. The Louann Salt is generally assigned the role of mother salt or source bed from which the many domal salt structures grew (Figure 6-9). Although the bedded salt is very thick in some areas as a result of salt flowage [seismic data indicate thicknesses greater than 1,006 meters (3,300 ft)], localized thinning is encountered and sometimes no salt is found near the base of some salt structures. The various theories involving salt movement and dome growth are presented in the Introduction, Background, and Summary Report, Volume I, Chapter 2 of the Area Characterization Report.

6.2.2.2 Jurassic: The Jurassic within the study area is represented by Lower Jurassic rocks, described above, and Upper Jurassic sediments, which consist of the Louark and Cotton Valley

Groups. The Louark Group consists of the Norphlet, Smackover Limestone, Buckner, and the Gilmer Limestone* Formations. The depositional history has been continuous, thus, all formations are conformable with each other. The transitional nature of the section is characterized by the evaporites (Louann Group) grading upward into clastics (Norphlet), and then into limestones (Buckner and Gilmer). The upper portions of each formation are time correlatives with lower portions of the formations above. This is a common feature of facies development which typically reflects rapidly changing conditions of deposition in a shallow marine environment. Seismic data indicate that the thickness of the Louark Group throughout the study area varies from less than 762 meters (2,500 ft) over deep salt structures to almost 1,219 meters (4,000 ft) in structural depressions adjacent to them (Figure 6-10).

The Cotton Valley Group is divided into three formations: the Bossier Formation at the base, the Schuler Formation, and the Knowles Limestone**. Well control data indicate that the unit is 509 meters (1,670 ft) thick north of Oakwood Dome and it thickens generally northeasterly, easterly, and in rim synclines adjacent

---

*Forgotson and Forgotson (1976) have suggested the name Gilmer Limestone for the uppermost formation of the Louark Group in lieu of the commonly used term, Cotton Valley Limestone. The Haynesville Formation grades laterally into the Gilmer Limestone of East Texas.

**Mann and Thomas (1964) proposed the name Knowles Limestone for the youngest formation of the Cotton Valley Group. This would replace the informal term Cotton Valley "B" Limestone generally used in East Texas.

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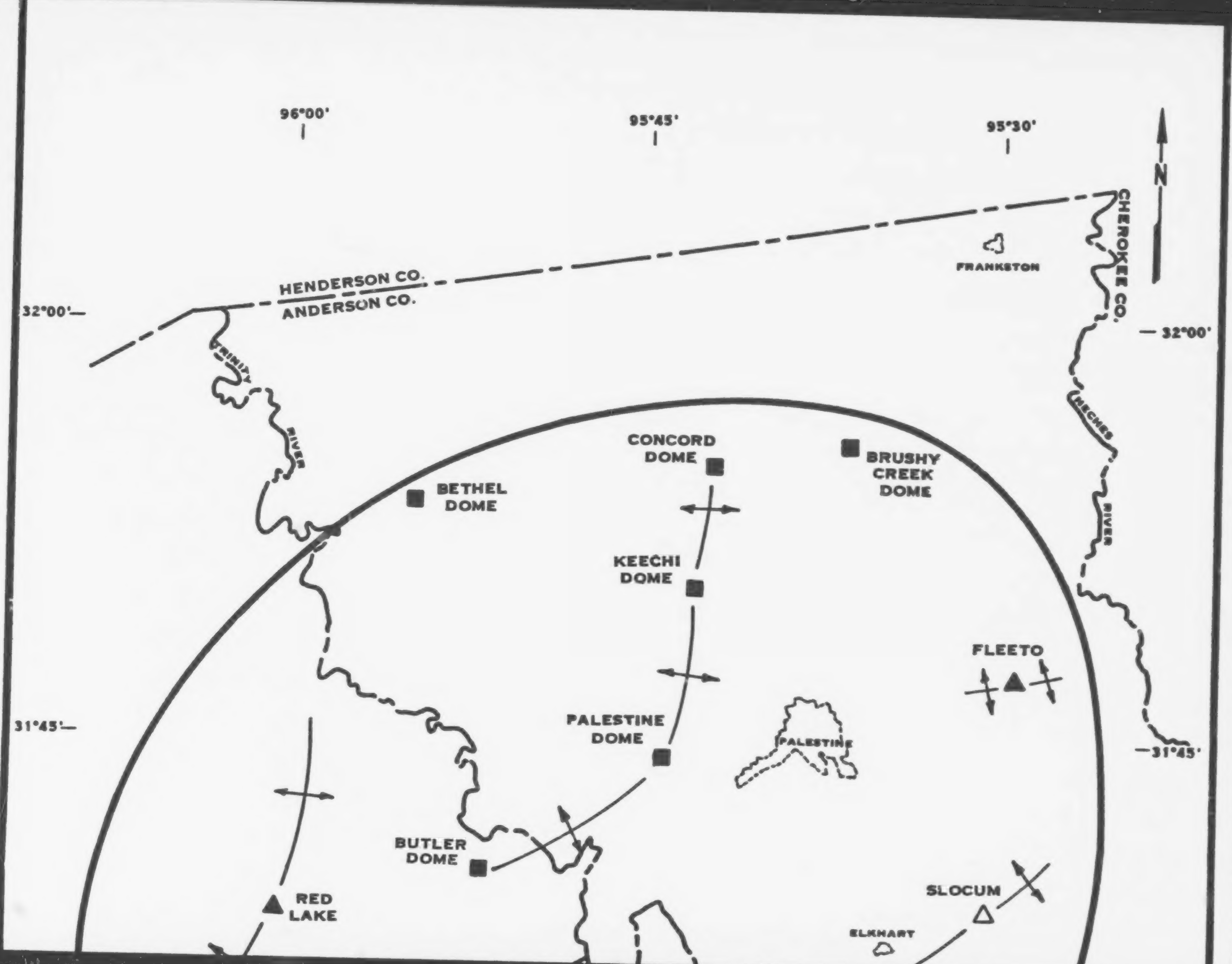
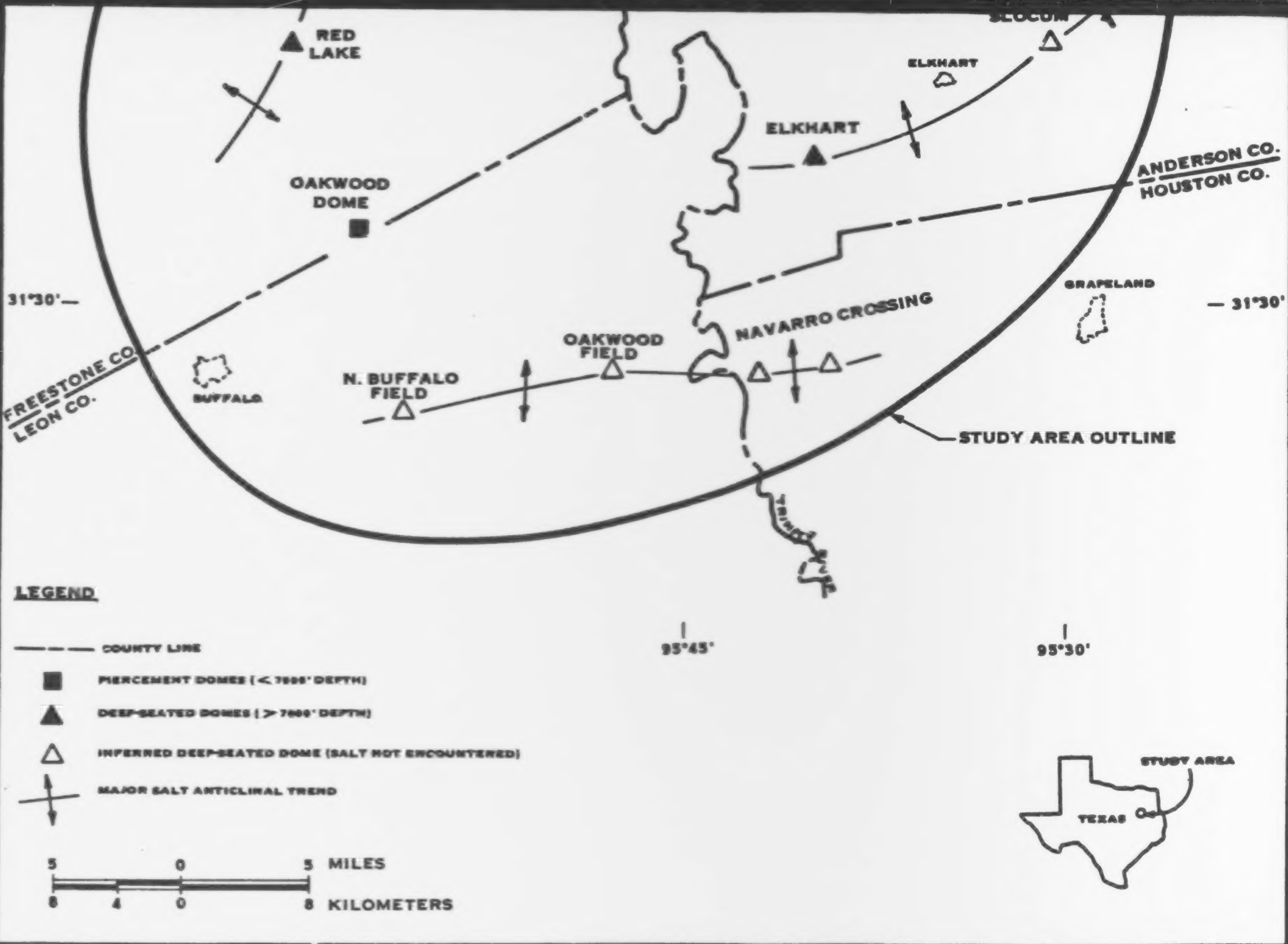

96°00'
95°45'
95°30'
N
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
32°00'
32°00'
TRINITY
RIVER
NECHES
RIVER
CONCORD DOME
BRUSHY CREEK DOME
BETHEL DOME
KEECHI DOME
FLEETO
PALESTINE DOME
PALESTINE
31°45'
31°45'
BUTLER DOME
RED LAKE
SLOCUM
ELKHART

BEST DOCUMENT AVAILABLE

22A

FIGURE 6-9


SLOCUM
RED LAKE
ELKHART
ELKHART
OAKWOOD DOME
ANDERSON CO.
HOUSTON CO.
31°30'
31°30'
GRAPELAND
NAVARRO CROSSING
OAKWOOD FIELD
FREESTONE CO.
LEON CO.
BUFFALO
N. BUFFALO FIELD
STUDY AREA OUTLINE
TRINITY RIVER
95°45'
95°30'
LEGEND
COUNTY LINE
PIERCEMENT DOMES (< 7000' DEPTH)
DEEP-SEATED DOMES (> 7000' DEPTH)
INFERRED DEEP-SEATED DOME (SALT NOT ENCOUNTERED)
MAJOR SALT ANTICLINAL TREND
STUDY AREA
TEXAS
5 0 5 MILES
8 4 0 8 KILOMETERS

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

SALT MASSES AND MAJOR SALT ANTICLINAL TRENDS

JOB NO. MV9600

FIGURE 6-9

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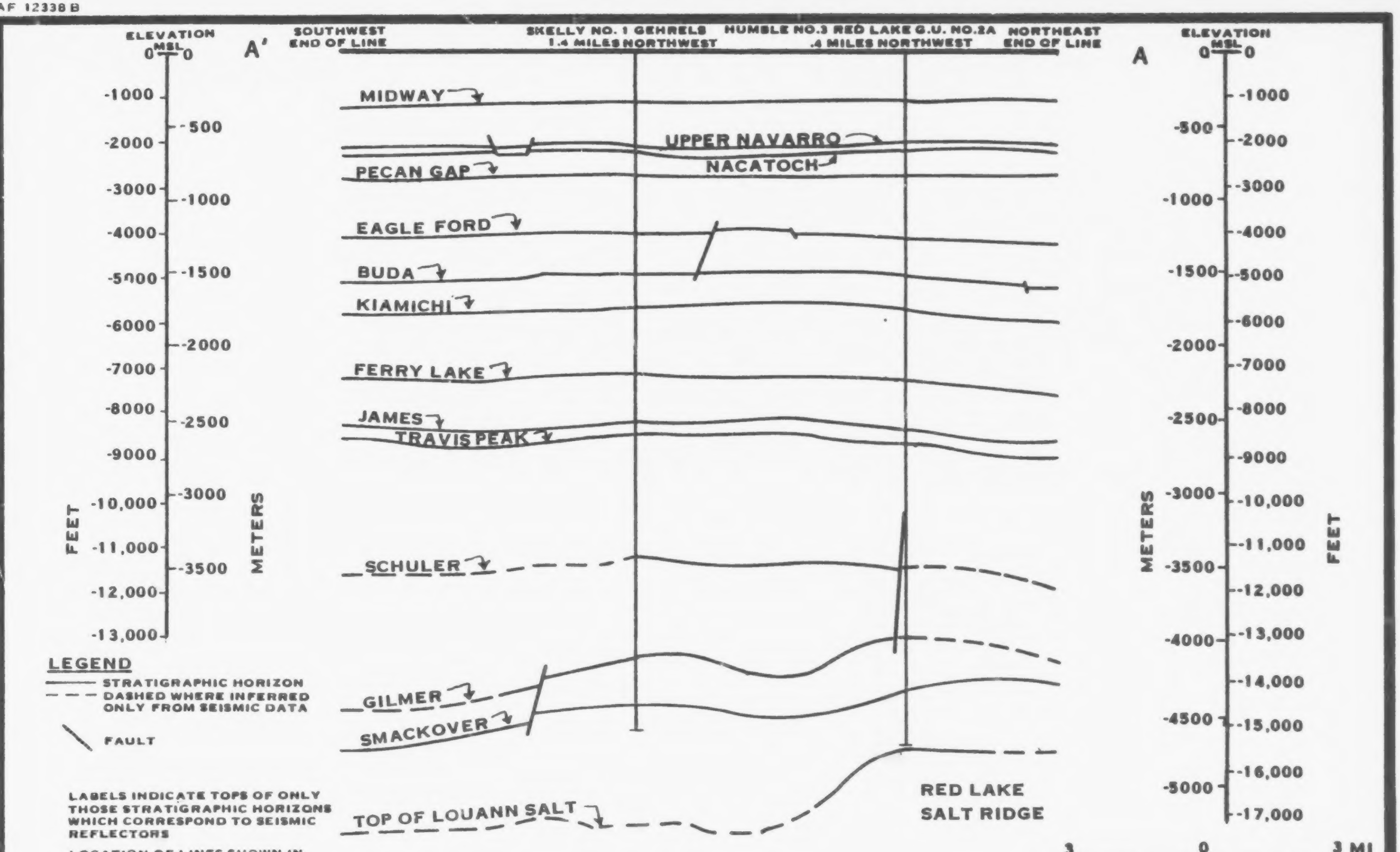
AF 12338 B


ELEVATION MSL
A'
SOUTHWEST END OF LINE
SKELLY NO. 1 GEHRELS 1.4 MILES NORTHWEST
HUMBLE NO.3 RED LAKE G.U. NO.2A .4 MILES NORTHWEST
NORTHEAST END OF LINE
A
ELEVATION MSL
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-12,000
-13,000
-14,000
-15,000
-16,000
-17,000
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
FEET
METERS
MIDWAY
UPPER NAVARRO
NACATOCH
PECAN GAP
EAGLE FORD
BUDA
KIAMICHI
FERRY LAKE
JAMES
TRAVIS PEAK
SCHULER
GILMER
SMACKOVER
TOP OF LOUANN SALT
RED LAKE SALT RIDGE
LEGEND
STRATIGRAPHIC HORIZON
DASHED WHERE INFERRED ONLY FROM SEISMIC DATA
FAULT
3
0
3 MI
4
0
4
KM

LABELS INDICATE TOPS OF ONLY THOSE STRATIGRAPHIC HORIZONS WHICH CORRESPOND TO SEISMIC REFLECTORS

LOCATION OF LINES SHOWN IN FIGURE 6-3

VERTICAL EXAGGERATION=5X

PREPARED		DATE	8/15/80
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REVISED		DATE	
APPROVED		DATE	8/15/80

T-1039-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

CROSS-SECTION A-A' BASED ON SEISMIC AND WELL DATA

JOB NO. MV9600

FIGURE 6-10

FIGURE 6-10

to salt structures. With the exception of the Knowles Limestone, these formations within the study area are composed of fine-grain clastics and shale in the Bossier, and sandstone in the Schuler, both with minor amounts of limestone. The group is a supratidal to deltaic facies and is conformable with the underlying Gilmer Limestone. Biostratigraphic dating (based on fossil markers) indicates that the top of the Cotton Valley Group, the Knowles Limestone, is transitional upward into Early Cretaceous beds (Todd and Mitchum, 1977).

6.2.2.3 Cretaceous: The Cretaceous System consists of the Comanchean and Gulfian Series, both of which are present within the study area.

6.2.2.3.1 Comanchean Series - The Comanchean Series is divided into three groups: the Trinity, the Fredericksburg, and the Washita.

The Trinity Group is composed of the Travis Peak Formation, the Pettet Formation, the Glen Rose Subgroup* (including the Lower Glen Rose, the Ferry Lake**, and the Upper Glen Rose Formations), and the Paluxy Formation. The sequence of formations is characterized by Travis Peak clastics grading upward into alternating limestone and clastics of the Lower Glen Rose

---

*Although some stratigraphers have proposed that the basal formation of the Trinity Group is the Glen Rose, the designation has not received wide usage in Texas.

**In East Texas, the term massive anhydrite is commonly used to denote the formation below the Upper Glen Rose Formation.

Formation, then into the Ferry Lake evaporites, into limestones, clastics, and evaporites of the Upper Glen Rose, and finally into clastics of the Paluxy Formation.

The thickness of the Trinity Group varies substantially, primarily as a result of the changes in thickness of the Travis Peak. Well data on anticlinal salt structures in the western portion of the study area indicate that the thickness of the group is approximately 1,676 meters (5,500 ft), with the Travis Peak accounting for 50 percent of the unit. On the flanks of salt structures, the Travis Peak Formation thickens, but the other formations of the Trinity Group are fairly constant in thickness. Farther to the north, northeast, and east, these Upper Trinity units thicken regionally because of proximity to the basin center of deposition (Figures 6-11 and 6-12). The isochore map presented in Figure 6-12 shows localized thickening of these units into rim synclines developed adjacent to specific domes.

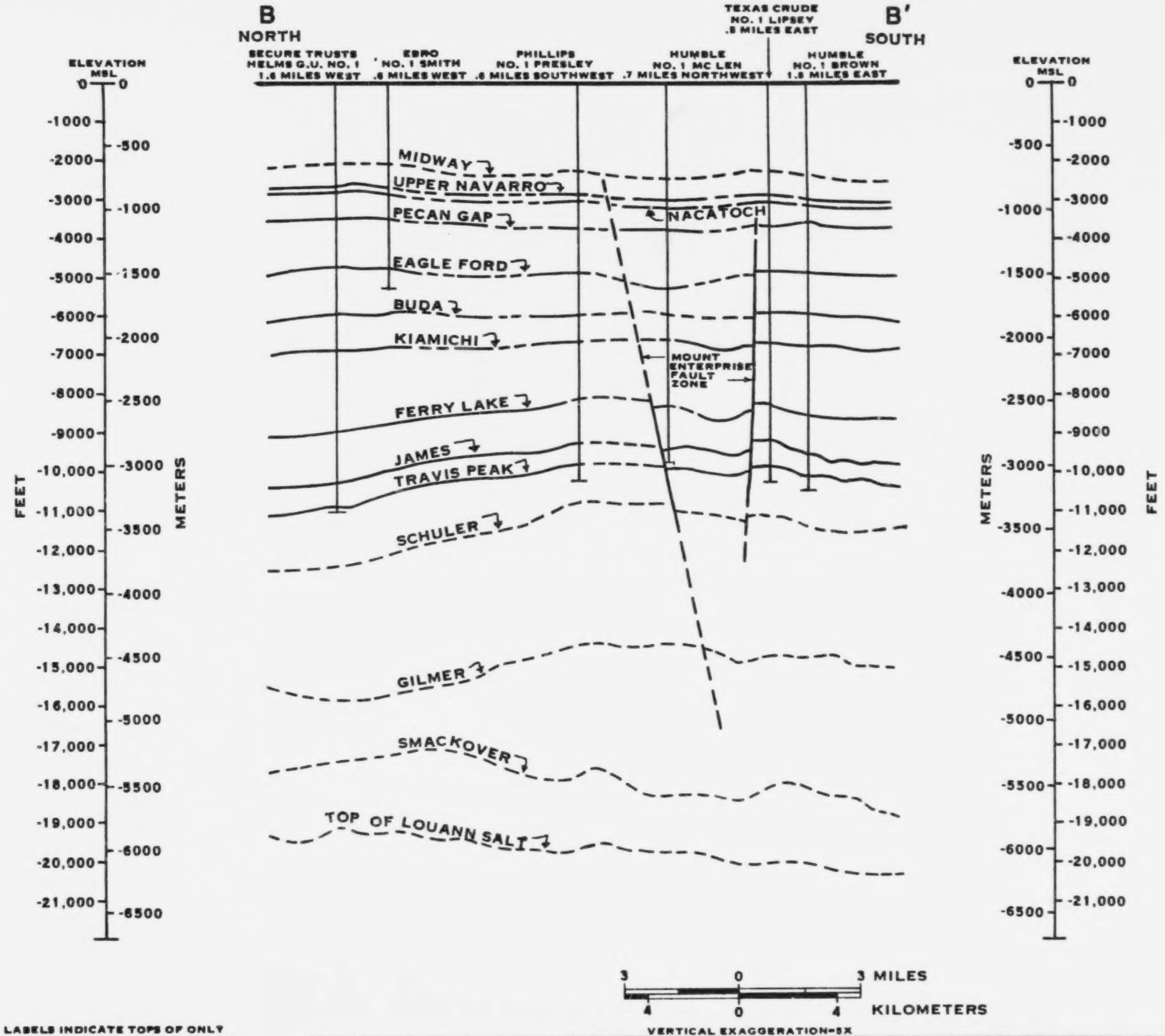
The Travis Peak is a delta plain facies, and the younger units of the Trinity Group are transitional from delta deposits to a carbonate shelf facies.

The Fredericksburg Group is composed of the Goodland and Kiamichi Formations. The Goodland is composed of limestones with interbedded clastic tongues and it grades upward into the Kiamichi Shale. The thickness of the Fredericksburg is about 107 meters (350 ft) in the western portion of the study area and it is conformable with the underlying Trinity Group. Except for local thickening in the center of the basin and in rim synclines adjacent to piercement domes, the Fredericksburg and overlying units vary little. There is no thickening peripheral to deep salt pillow structures, indicating that salt movement into these deeper structures had stopped prior to the deposition of the Fredericksburg Group.

The Washita Group consists of (from bottom to top) the Georgetown Subgroup, the Grayson Shale, the Buda Limestone, and the Maness Shale. The Washita Group is lithologically characterized as alternating beds of limestones and clastics. The lithology of the entire section persists along strike with little change throughout the study area. The thickness of the entire group, except for the Maness Shale, varies from approximately 183 to >366 meters (600 to >1,200 ft). The greater thicknesses are reflected in specific domal areas (Figure 6-13). The Washita Group is conformable upon the Fredericksburg Group within the study area and it is the youngest sequence of the Comanchean Series.

6.2.2.3.2 Gulfian Series - The Gulfian Series is composed of the Woodbine, Eagle Ford, Austin, Taylor, and Navarro Groups. The lithology of the series is dominantly clastic, consisting of sandstones and shales interbedded with some calcareous deposits.

The Woodbine Group is subdivided into various formations throughout most of the outcrop area in northeast Texas; however, subdivisions are not recognized in the subsurface. Downdip from the outcrop the Woodbine Group consists of calcareous to noncalcareous, very fine to medium-grain size, well-sorted


B
NORTH
B'
SOUTH
SECURE TRUSTS HELMS G.U. NO. 1 1.6 MILES WEST
EBRO NO. 1 SMITH .6 MILES WEST
PHILLIPS NO. 1 PRESLEY .6 MILES SOUTHWEST
HUMBLE NO. 1 MC LEN .7 MILES NORTHWEST
TEXAS CRUDE NO. 1 LIPSEY .8 MILES EAST
HUMBLE NO. 1 BROWN 1.8 MILES EAST
ELEVATION MSL
FEET
METERS
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-12,000
-13,000
-14,000
-15,000
-16,000
-17,000
-18,000
-19,000
-20,000
-21,000
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000
-6500
MIDWAY
UPPER NAVARRO
NACATOCH
PECAN GAP
EAGLE FORD
BUDA
KIAMICHI
MOUNT ENTERPRISE FAULT ZONE
FERRY LAKE
JAMES
TRAVIS PEAK
SCHULER
GILMER
SMACKOVER
TOP OF LOUANN SALT
3
0
3 MILES
4
0
4
KILOMETERS
VERTICAL EXAGGERATION=5X

LEGEND

STRATIGRAPHIC HORIZON
DASHED WHERE INFERRED ONLY FROM SEISMIC DATA

FAULT - DASHED WHERE INFERRED

LABELS INDICATE TOPS OF ONLY THOSE STRATIGRAPHIC HORIZONS WHICH CORRESPOND TO SEISMIC REFLECTORS

LOCATION OF LINE SHOWN IN FIGURE 6-3

PREPARED	JH	DATE	8/15/80
REVISED	GHF	DATE	11/9/81
REVISED		DATE	
APPROVED	GHF	DATE	8/15/80

T-1460-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

CROSS-SECTION B-B' BASED ON SEISMIC AND WELL DATA

JOB NO. MV9600

FIGURE 6-11

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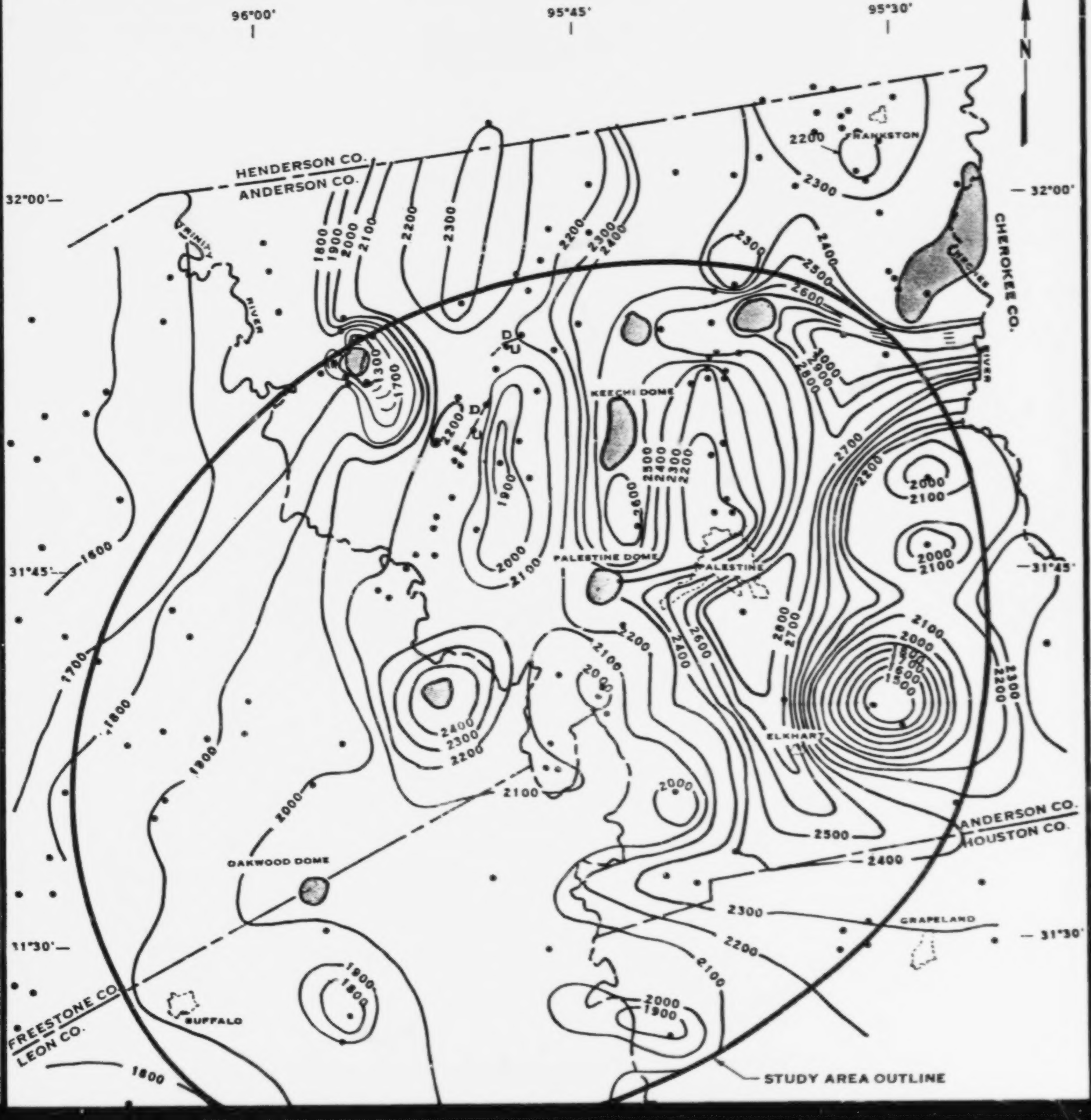
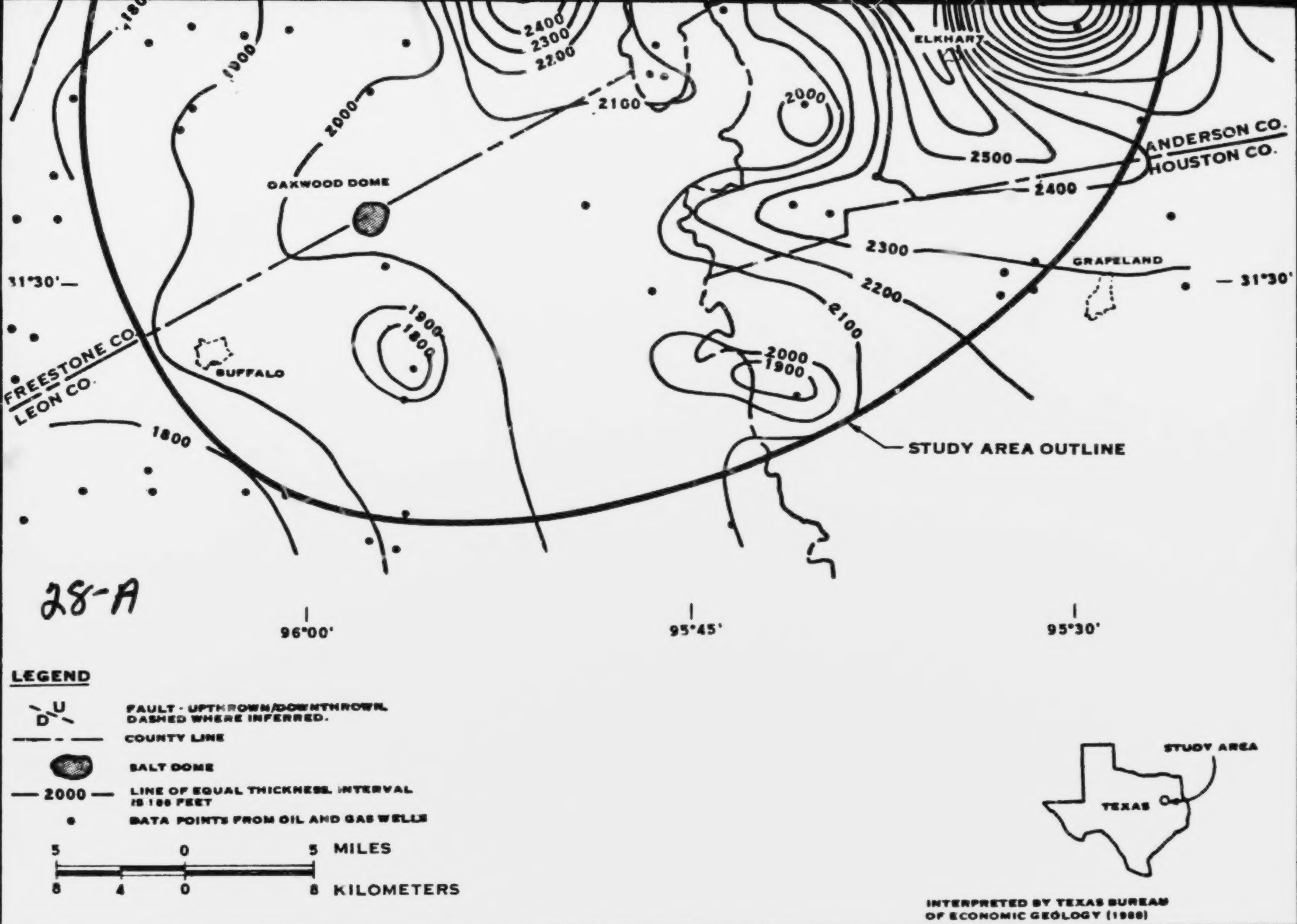
28



96°00'
95°45'
95°30'
N
32°00'
31°45'
31°30'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FREESTONE CO.
LEON CO.
ANDERSON CO.
HOUSTON CO.
TRINITY
RIVER
NECHES
RIVER
FRANKSTON
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
OAKWOOD DOME
GRAPELAND
BUFFALO
STUDY AREA OUTLINE
D
U
1300
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000


2400
2300
2200
1800
1900
2000
2100
ELKHART
2000
ANDERSON CO.
HOUSTON CO.
2500
2400
OAKWOOD DOME
2300
GRAPELAND
31°30'
31°30'
2200
2100
FREESTONE CO.
LEON CO.
1900
1800
BUFFALO
2000
1900
1800
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
D U
FAULT - UPTHROWN/DOWNTHROWN, DASHED WHERE INFERRED.
COUNTY LINE
SALT DOME
2000
LINE OF EQUAL THICKNESS, INTERVAL IS 100 FEET
DATA POINTS FROM OIL AND GAS WELLS
5
0
5
MILES
8
4
0
8
KILOMETERS
STUDY AREA
TEXAS

28-A

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

PREPARED		DATE	8/15/80
REVISED	GHF	DATE	11/9/81
REVISED		DATE	
APPROVED		DATE	8/15/80

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NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

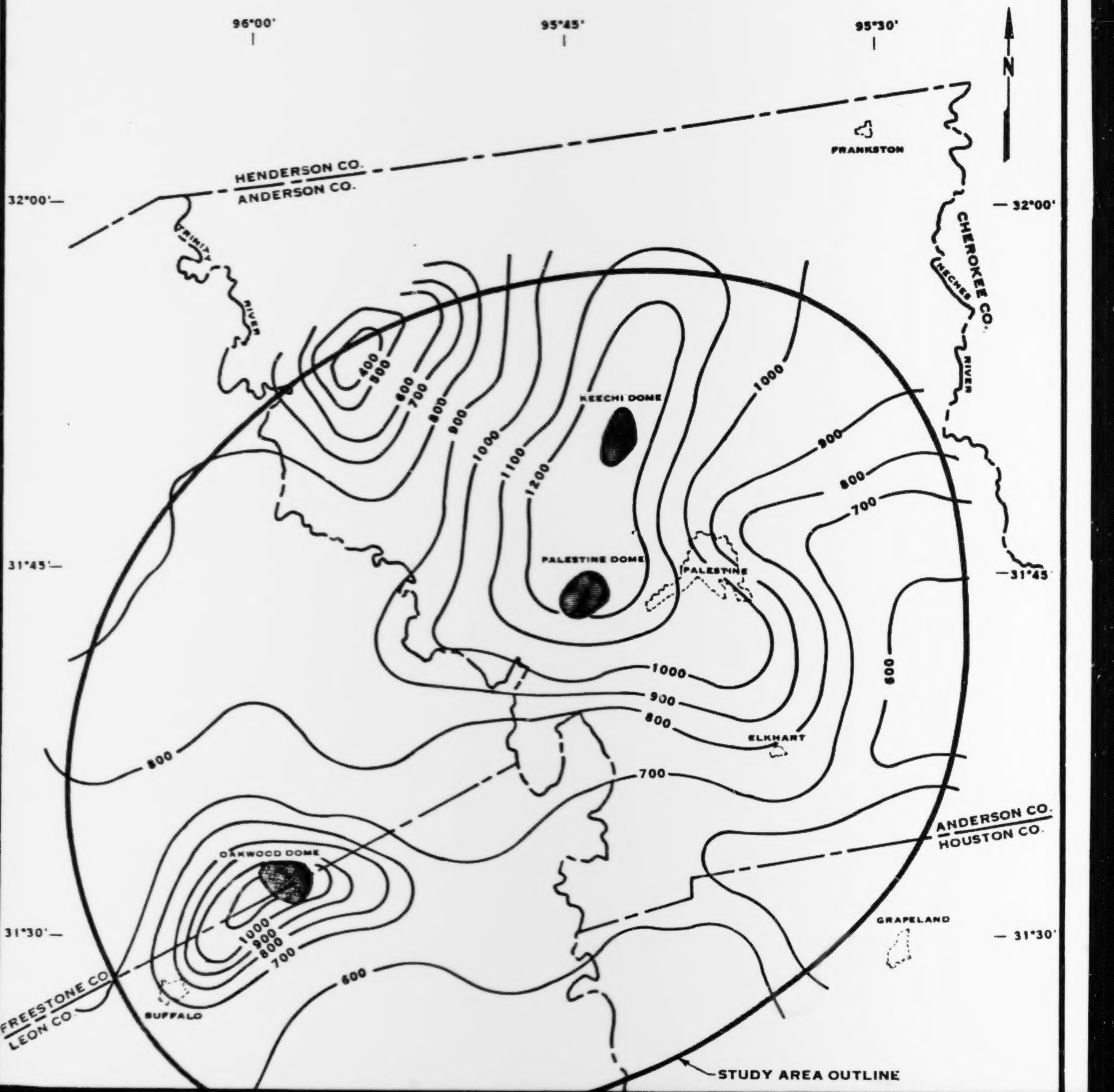
EAST TEXAS STUDY AREA

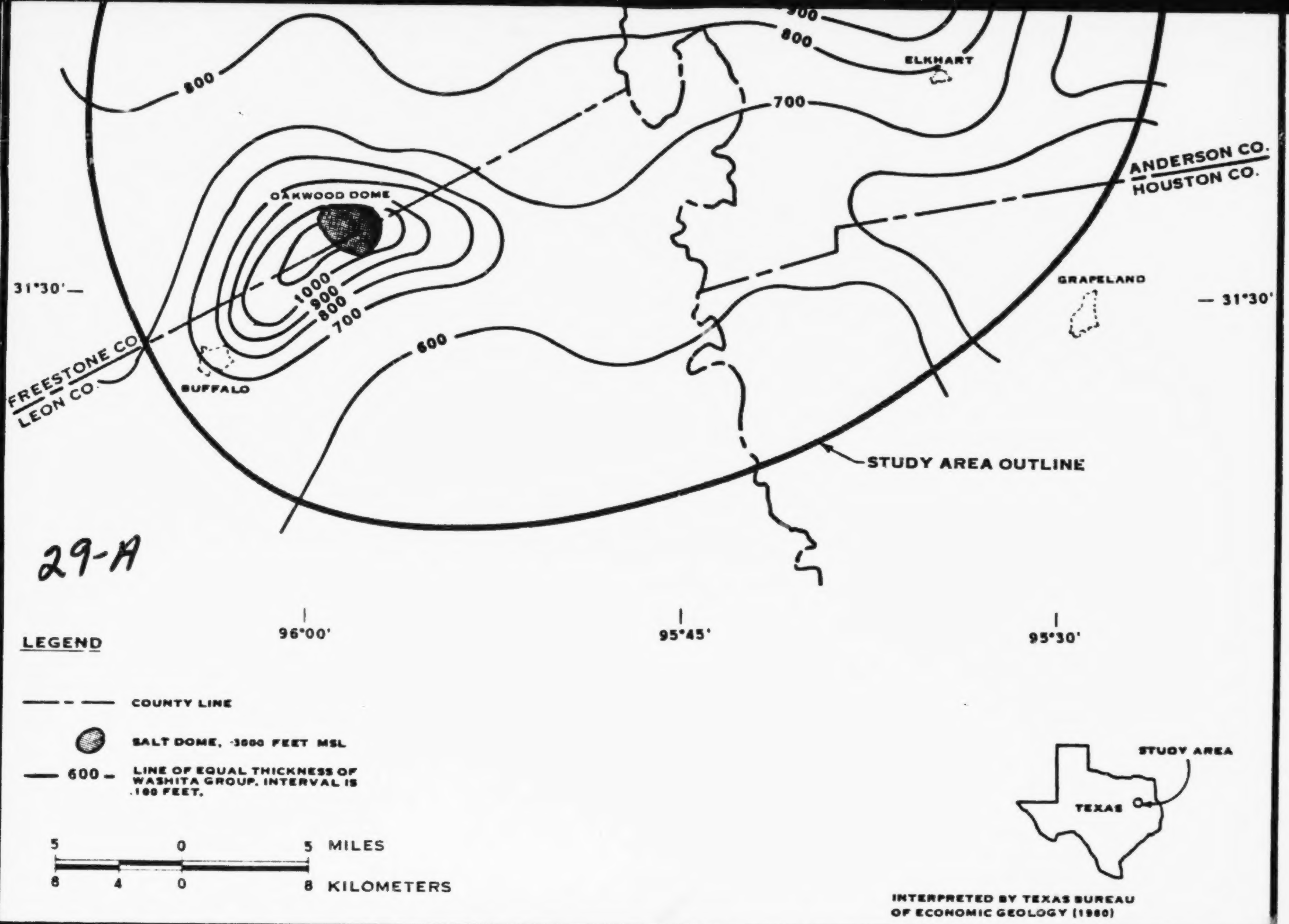
ISOCHORE - TOP OF JAMES TO TOP OF GLEN ROSE SUBGROUP

JOB NO. MV9600

FIGURE 6-12

29


96°00'
95°45'
95°30'
N
32°00'
31°45'
31°30'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FREESTONE CO.
LEON CO.
HOUSTON CO.
TRINITY RIVER
NECHES RIVER
FRANKSTON
KEECHI DOME
PALESTINE DOME
PALESTINE
OAKWOOD DOME
ELKHART
GRAPELAND
BUFFALO
400
500
600
700
800
900
1000
1100
1200
600
700
800
900
1000
STUDY AREA OUTLINE


900
800
800
ELKHART
700
ANDERSON CO.
HOUSTON CO.
OAKWOOD DOME
1000
900
800
700
600
31°30'
31°30'
GRAPELAND
FREESTONE CO.
LEON CO.
BUFFALO
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
COUNTY LINE
SALT DOME, -3000 FEET MSL
600
LINE OF EQUAL THICKNESS OF WASHITA GROUP, INTERVAL IS 100 FEET.
5
0
5
MILES
8
4
0
8
KILOMETERS
STUDY AREA
TEXAS

29-A

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

PREPARED [illegible] DATE [illegible]
REVISED GHF DATE 11/9/81
REVISED ______ DATE ______
APPROVED [illegible] DATE [illegible]

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

ISOCHORE - WASHITA GROUP

JOB NO. MV9600

FIGURE 6-13

andstone. The sandstone is interbedded with shales and mudtones, representing transition from a fluvial-deltaic to strand o shallow marine shelf facies. The variation in thickness of he Woodbine (Figure 6-14) is from approximately 107 to >244 eters (350 to >800 ft). The greatest thicknesses are located in asinal centers of deposition in the northeastern and central portions of the study area. The base of the Woodbine is placed t the lowermost sandstone and it is locally conformable with nderlying units.

The Eagle Ford Group consists primarily of very fine micaceous shale with minor amounts of glauconitic, very micaceous, porous to nonporous sandstone. The uppermost sandstone is usually termed the Sub-Clarksville Sand. The Eagle Ford is 30 to 152 meters (100 to 500 ft) thick in the study area. It is a continuation of Woodbine strand-plain shelf sedimentation and it contains an abundance of microfossils. The Eagle Ford Group conformably overlies the Woodbine Group.

The Austin Group consists predominantly of argillaceous, fossiliferous, and chalky limestone, interbedded with thin beds of micaceous shale. The Austin can be subdivided (from bottom to top) into the lower Ector Chalk (commonly called Austin Chalk in northeast Texas), Middle Austin, and the upper Gober Chalk. The Austin Group, a marine-shelf facies with thicknesses varying from 198 to 229 meters (650 to 750 ft), unconformably overlies the Eagle Ford.

In the subsurface the Taylor Group is divided into three formations: the Lower Taylor, the Pecan Gap Chalk, and the Upper

Taylor. The Lower Taylor in the study area consists of micaceous, glauconitic, calcareous to noncalcareous shale. The uppe part of the Lower Taylor is the thin-bedded, argillacous, glauconitic, very-fine-grain, porous to nonporous Wolfe City Sandstone. The middle unit, the Pecan Gap, is a microfossiliferous chalk. The Upper Taylor consists predominantly of microfossiliferous marl and flaky, slightly calcareous shale. At several stratigraphic levels within the Taylor Group, thin beds of bentonite are present. The Taylor is 213 to 259 meters (700 to 850 ft) thick within the study area and it is the product of marine-shelf sedimentation. It is conformable with the underlying Austin Group and with the overlying Navarro Group. An isochore map (Figure 6-15) of the interval from the top of the Pecan Gap to the base of the Austin Chalk shows thickening of the units into rim synclines adjacent to specific salt domes.

The Navarro Group is subdivided into three parts, Lower Navarro, Nacatoch Sand and Upper Navarro*. The Navarro Group consists of microfossiliferous, micaceous shale, interbedded with marly, calcareous, nonporous sandstone and very thin stringers of bentonite. The Nacatoch is characterized by beds of fossiliferous, calcareous, porous to nonporous sandstone in the northern portion of the study area, and in the southern portion by a sandy marl. The Navarro ranges in thickness from 168 to 198 meters

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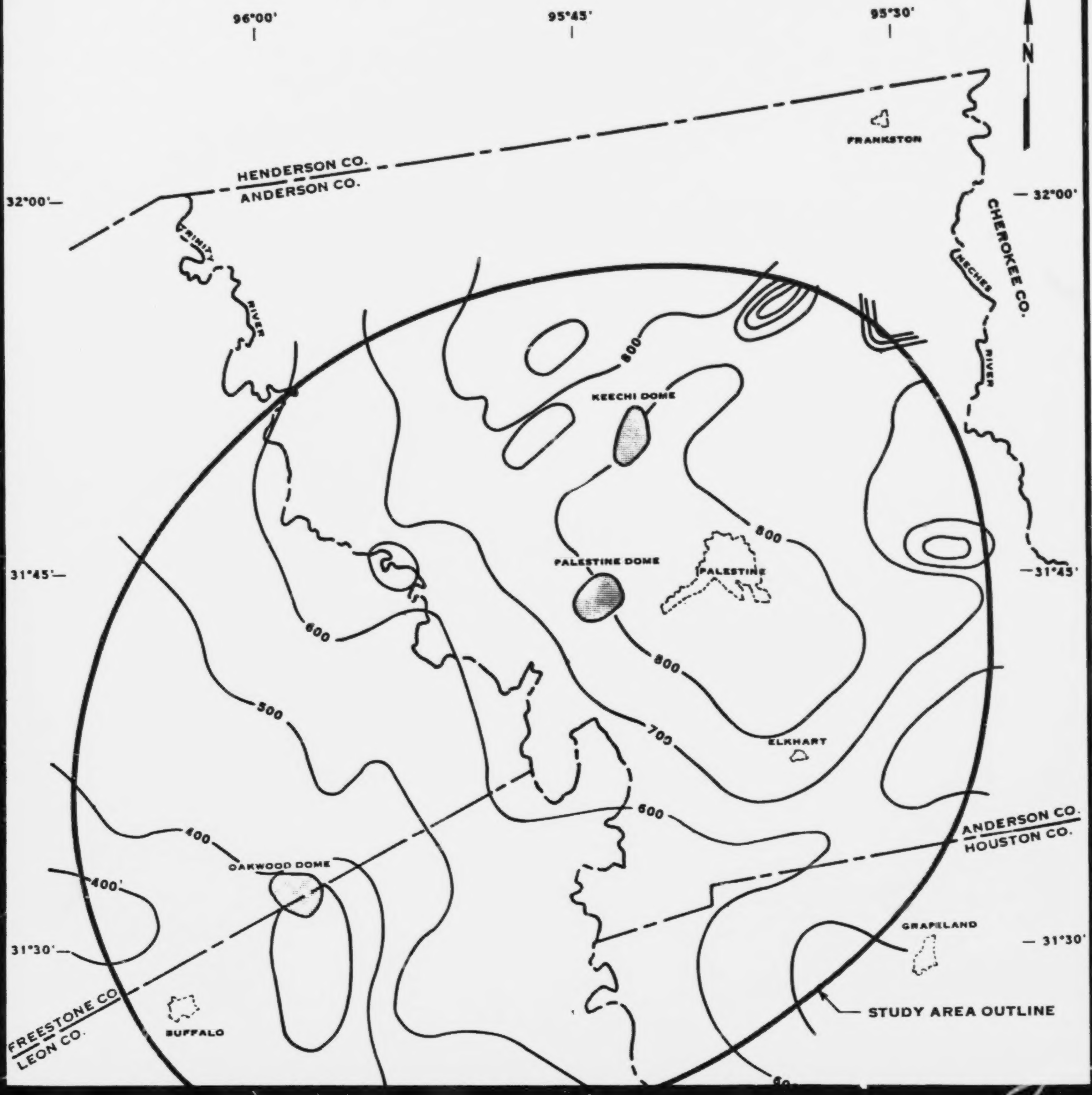
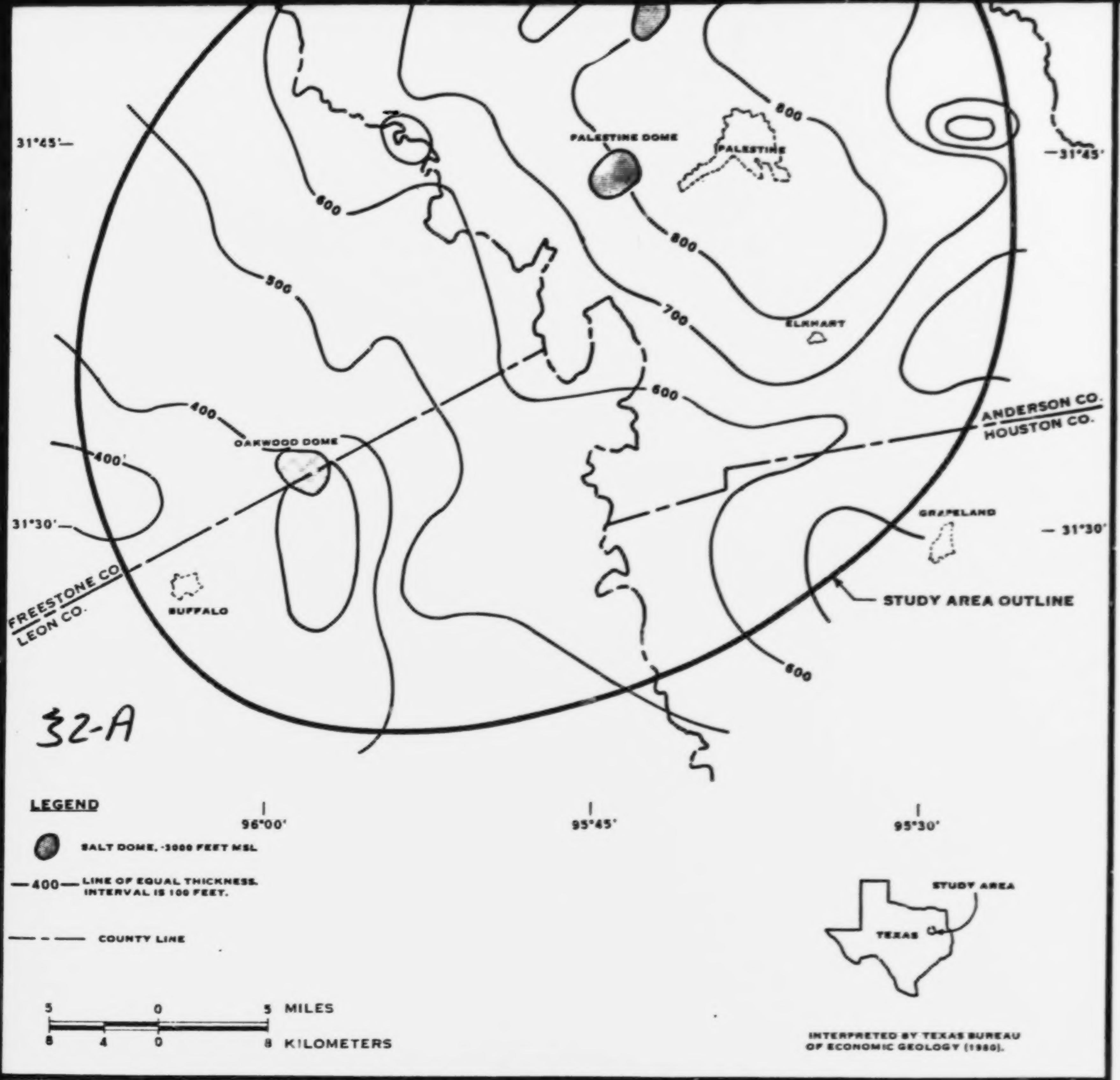
*The Texas Bureau of Economic Geology (BEG) has divided the Upper Navarro into an upper clay and lower marl zone for mapping purposes.

32


96°00'
95°45'
95°30'
N
FRANKSTON
HENDERSON CO.
ANDERSON CO.
32°00'
32°00'
TRINITY
RIVER
NECHES
RIVER
CHEROKEE CO.
800
KEECHI DOME
800
PALESTINE DOME
PALESTINE
31°45'
31°45'
600
800
500
700
ELKHART
600
400
OAKWOOD DOME
400'
ANDERSON CO.
HOUSTON CO.
GRAPELAND
31°30'
31°30'
STUDY AREA OUTLINE
FREESTONE CO.
LEON CO.
BUFFALO


31°45'
31°45'
31°30'
31°30'
PALESTINE DOME
PALESTINE
800
800
800
600
500
700
600
600
400
400'
OAKWOOD DOME
ELKHART
GRAPELAND
BUFFALO
ANDERSON CO.
HOUSTON CO.
FREESTONE CO.
LEON CO.
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
SALT DOME, -3000 FEET MSL
—400— LINE OF EQUAL THICKNESS. INTERVAL IS 100 FEET.
COUNTY LINE
5
0
5
MILES
8
4
0
8
KILOMETERS
STUDY AREA
TEXAS

32-A

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980).

PREPARED __________ DATE 2/25/80
REVISED GHF DATE 11/9/81
REVISED __________ DATE __________
APPROVED __________ DATE 5/15/80

T-1073-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
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EAST TEXAS STUDY AREA

ISOCHORE - WOODBINE GROUP

JOB NO. MV9600

FIGURE 6-14

33

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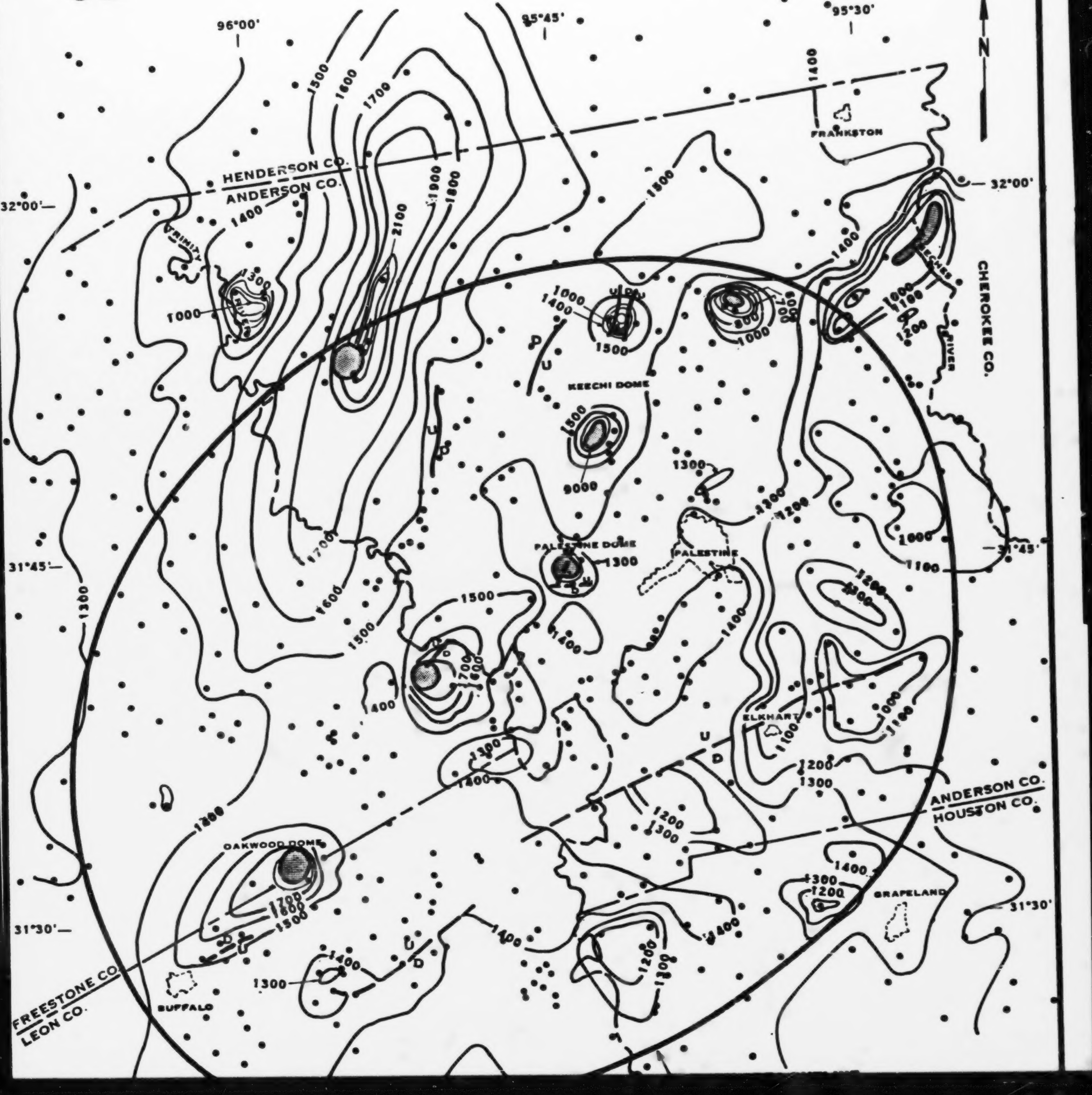
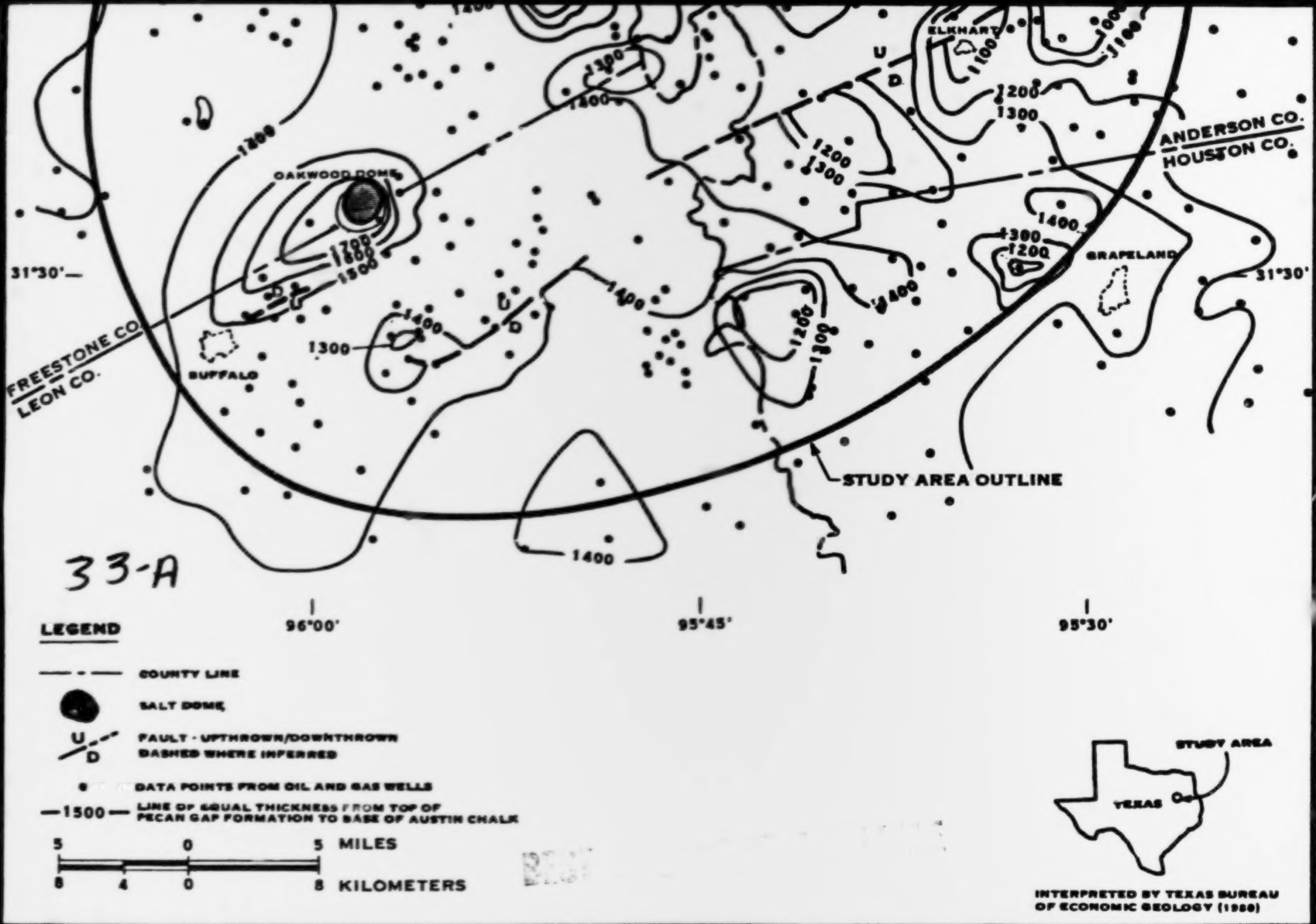

96°00'
95°45'
95°30'
N
32°00'
31°45'
31°30'
HENDERSON CO.
ANDERSON CO.
FRANKSTON
TRINITY
CHEROKEE CO.
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
OAKWOOD DOME
GRAPELAND
BUFFALO
FREESTONE CO.
LEON CO.
HOUSTON CO.
U
D
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2100
800
900
9000

33-A


ELKHART
U
D
1100
1200
1300
1400
ANDERSON CO.
HOUSTON CO.
OAKWOOD DOME
1700
1600
1500
31°30'
GRAPELAND
FREESTONE CO.
LEON CO.
BUFFALO
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
COUNTY LINE
SALT DOME
FAULT - UPTHROWN/DOWNTHROWN
DASHED WHERE INFERRED
DATA POINTS FROM OIL AND GAS WELLS
—1500— LINE OF EQUAL THICKNESS FROM TOP OF PECAN GAP FORMATION TO BASE OF AUSTIN CHALK
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

PREPARED GH DATE 8/15/80
REVISED GHF DATE 11/9/81
REVISED DATE
APPROVED DATE 8/15/80

T-1456-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

ISOCHORE - TOP OF PECAN GAP FORMATION TO BASE AUSTIN CHALK

JOB NO. MV9600

FIGURE 6-15

(550 to 650 ft) in the study area and it is representative of marine-shelf sedimentation with minor clastic influx during the time of Nacatoch deposition. The contact of the Navarro with the overlying Midway Group is disconformable (Murray, 1961).

6.2.2.4 Tertiary: The Paleocene and Eocene Series of the Tertiary System are composed of the Midway, Wilcox, and the Claiborne Groups. In the study area, as throughout East Texas, the depositional history of the Tertiary System is characterized by four sequences:

(1) Wilcox sequence, consisting of the Midway and Wilcox and the Carrizo Formation

(2) Queen City sequence, consisting of the Reklaw and Queen City Formations

(3) Sparta sequence, consisting of the Weches and Sparta Formations

(4) Yegua sequence, consisting of the Cook Mountain and Yegua Formations.

6.2.2.4.1 Paleocene - The Paleocene Series consists of the Midway Group and the lower part of the Wilcox Group. Both groups are undifferentiated in the subsurface of the study area.

The Midway Group consists predominantly of micaceous, calcareous to noncalcareous shale. Thin beds of very fine-grain sandstone and siderite are found near the top of the upper Midway. The lower Midway contains thin beds of glauconitic sandstone. The Midway Group is overlain conformably by the Wilcox

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Group and ranges in thickness from 168 to 213 meters (550 to 700 ft).

The Wilcox Group consists of very fine-grain silts to coarse-grain sands which are occasionally indurated. Bedded lignite, siderite, and ironstone with stringers of bentonite are present throughout the Wilcox. In the western portion of the study area the Wilcox outcrop area is extensive (Figures 6-7 and 6-16). The Wilcox Group thickens southward into a major center of deposition where it reaches a thickness of 975 meters (3,200 ft) (Figure 6-16). Locally, the units thicken toward specific domes, denoting the presence of rim synclines (Figure 6-16). The biostratigraphy indicates a late Paleocene to early Eocene age for this group, which is unconformably overlain by the Claiborne Group.

6.2.2.4.2 Eocene - The Eocene Series consists of the upper part of the Wilcox Group and the Claiborne Group.

The Claiborne Group within the study area consists of six formations (from bottom to top): the Carrizo, Reklaw, Queen City, Weches, Sparta, and Cook Mountain Formations. The Claiborne Group consists of silts and very fine to coarse-grain, massive to thin-bedded sands. Some calcareous to noncalcareous clays, glauconite, marl, limestone, and lignite are found. Indurated glauconitic beds occur within the Claiborne. The Cook Mountain, Weches, and Reklaw Formations are generally characterized by the fine-grain, silty sediments; whereas the interbedded Carrizo, Queen City, and Sparta Formations are more sandy. The Claiborne Group outcrops in the western portion of the study area

36

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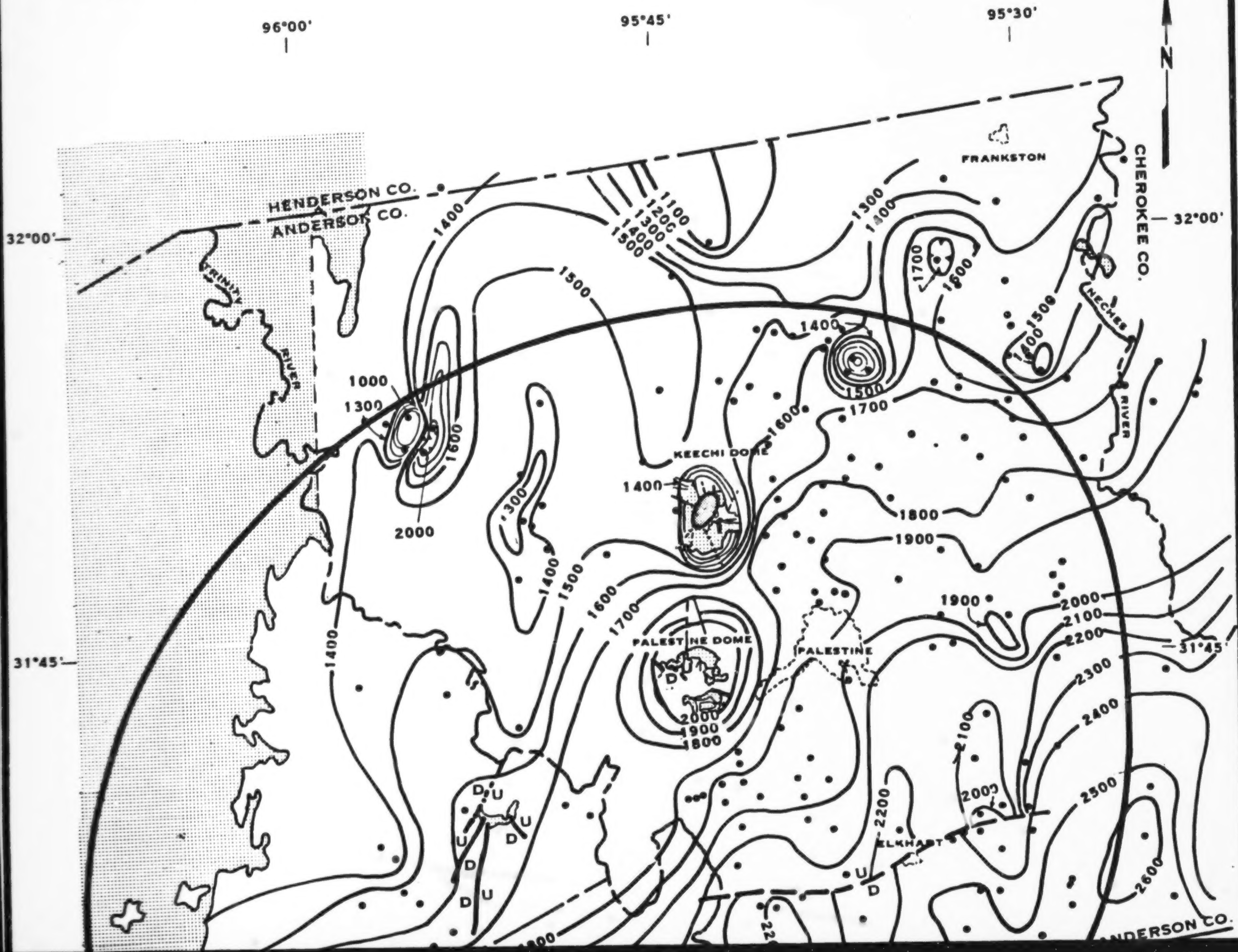
96°00'
95°45'
95°30'
N
32°00'
31°45'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
TRINITY RIVER
NECHES RIVER
FRANKSTON
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
1000
1100
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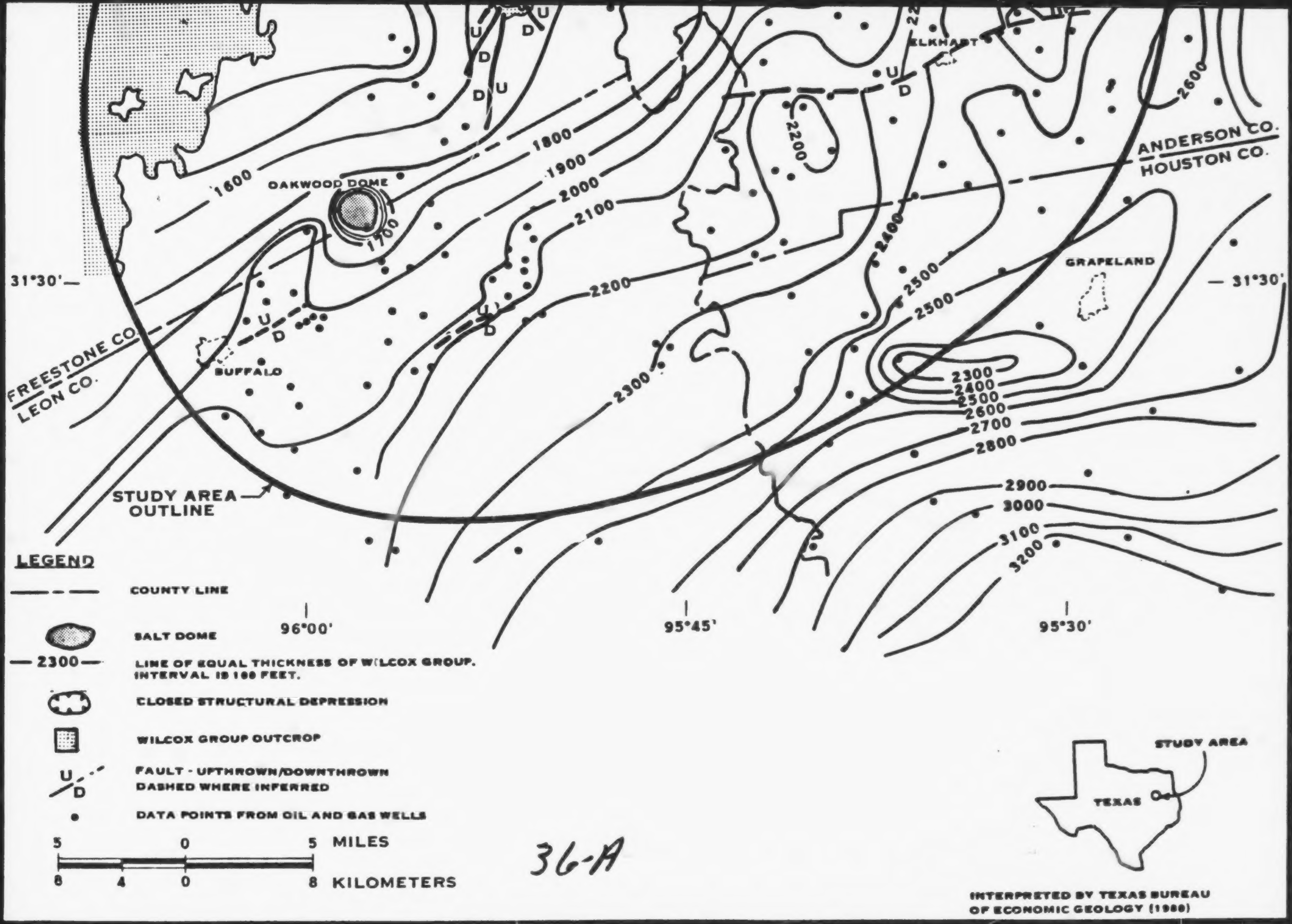


ELKHART
U
D
2200
2600
ANDERSON CO.
HOUSTON CO.
1600
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
1700
OAKWOOD DOME
GRAPELAND
BUFFALO
FREESTONE CO.
LEON CO.
31°30'
31°30'
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
COUNTY LINE
SALT DOME
2300
LINE OF EQUAL THICKNESS OF WILCOX GROUP. INTERVAL IS 100 FEET.
CLOSED STRUCTURAL DEPRESSION
WILCOX GROUP OUTCROP
FAULT - UPTHROWN/DOWNTHROWN DASHED WHERE INFERRED
DATA POINTS FROM OIL AND GAS WELLS
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS
INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

36-A

PREPARED [illegible] DATE [illegible]
REVISED GHF DATE 11/9/81
REVISED DATE
APPROVED [illegible] DATE [illegible]

T-1454-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

ISOCHORE - WILCOX GROUP

JOB NO. MV9600

FIGURE 6-16

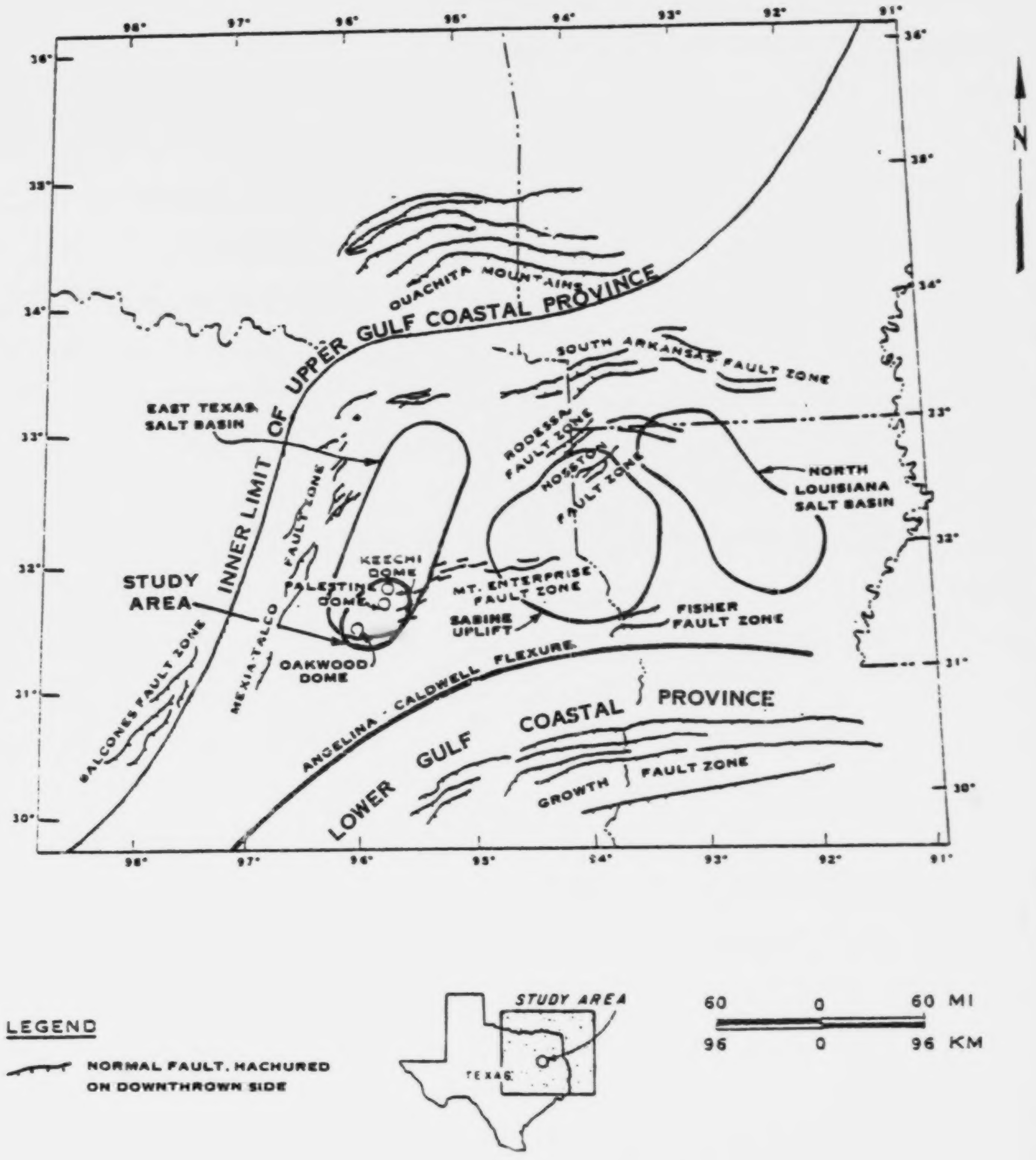
and thickens by 122 to 244 meters (400 to 800 ft) toward the east and southeast. The major center of deposition in the Claiborne is situated south of the study area.

6.2.2.5 Quaternary: The Quaternary System consists of two series, the Pleistocene and the Holocene. Quaternary sediments are not present throughout the entire basin but are found as terraces in isolated areas, usually in the vicinity of major drainage channels and flood plains (Figure 6-7). The sediments consist of sand, clay, silt, and some gravel lying unconformably upon Tertiary beds. Although the thicknesses of Quaternary sediments vary considerably with age and relationship to existing drainage channels, they are generally less than 6 meters (20 ft) thick in the study area.

6.2.3 STRUCTURE: The study area occupies the south-central and southeastern portion of the East Texas Salt Basin, which is situated along the axis of the Northeast Texas Embayment (Figure 6-17). The embayment is a geological feature which began as a crustal depression and received Triassic to middle Tertiary sediments. Major structural features peripheral to the study area include the Mexia-Talco Fault Zone to the west and north and the Sabine Uplift to the east. The Mt. Enterprise Fault Zone is the most prominent structural feature within the study area (Figure 6-17).

The Mexia-Talco Fault Zone (Figure 6-17) consists of a series of parallel normal faults that delineate a system of horsts and

[redacted]



98°
97°
96°
95°
94°
93°
92°
91°
36°
35°
34°
33°
32°
31°
30°
N
OUACHITA MOUNTAINS
INNER LIMIT OF UPPER GULF COASTAL PROVINCE
SOUTH ARKANSAS FAULT ZONE
EAST TEXAS SALT BASIN
RODESSA FAULT ZONE
HOSSTON FAULT ZONE
NORTH LOUISIANA SALT BASIN
MEXIA-TALCO FAULT ZONE
KEECHI DOME
PALESTINE DOME
STUDY AREA
MT. ENTERPRISE FAULT ZONE
SABINE UPLIFT
FISHER FAULT ZONE
OAKWOOD DOME
BALCONES FAULT ZONE
ANGELINA - CALDWELL FLEXURE
LOWER GULF COASTAL PROVINCE
GROWTH FAULT ZONE
LEGEND
NORMAL FAULT, HACHURED ON DOWNTHROWN SIDE
STUDY AREA
TEXAS
60 0 60 MI
96 0 96 KM

PREPARED TH DATE 8/15/8 REVISED GHF DATE 11/9/81 REVISED ____ DATE ____ APPROVED EWK DATE 8/15/ T-1078-1	NATIONAL WASTE TERMINAL STORAGE PROGRAM GEOLOGIC EVALUATION GULF COAST SALT DOMES LAW ENGINEERING TESTING COMPANY MARIETTA GEORGIA	EAST TEXAS STUDY AREA **REGIONAL MESOZOIC AND CENOZOIC STRUCTURAL ELEMENTS** JOB NO MV9600 FIGURE 6-17

BEST DOCUMENT AVAILABLE [redacted] 38

grabens roughly aligned with the strike of the Upper Cretaceous outcrop belt. This belt is the northern limit of the Gulf Coast Basin in this area (Nichols and others, 1968).

The Sabine Uplift is a dome-like feature with a diameter of approximately 145 km (90 mi), which separates the East Texas Basin from the Northern Lousiana Salt Basin. The Sabine Uplift was a slightly positive structural element during Upper Jurassic time and became submergent during Lower Cretaceous deposition (Nichols, 1964). The uplift was emergent at the beginning of the Upper Cretaceous, developing a slight angular unconformity at the base of the Austin Group. The Sabine Uplift has remained structurally positive since early Tertiary time (Nichols, 1964).

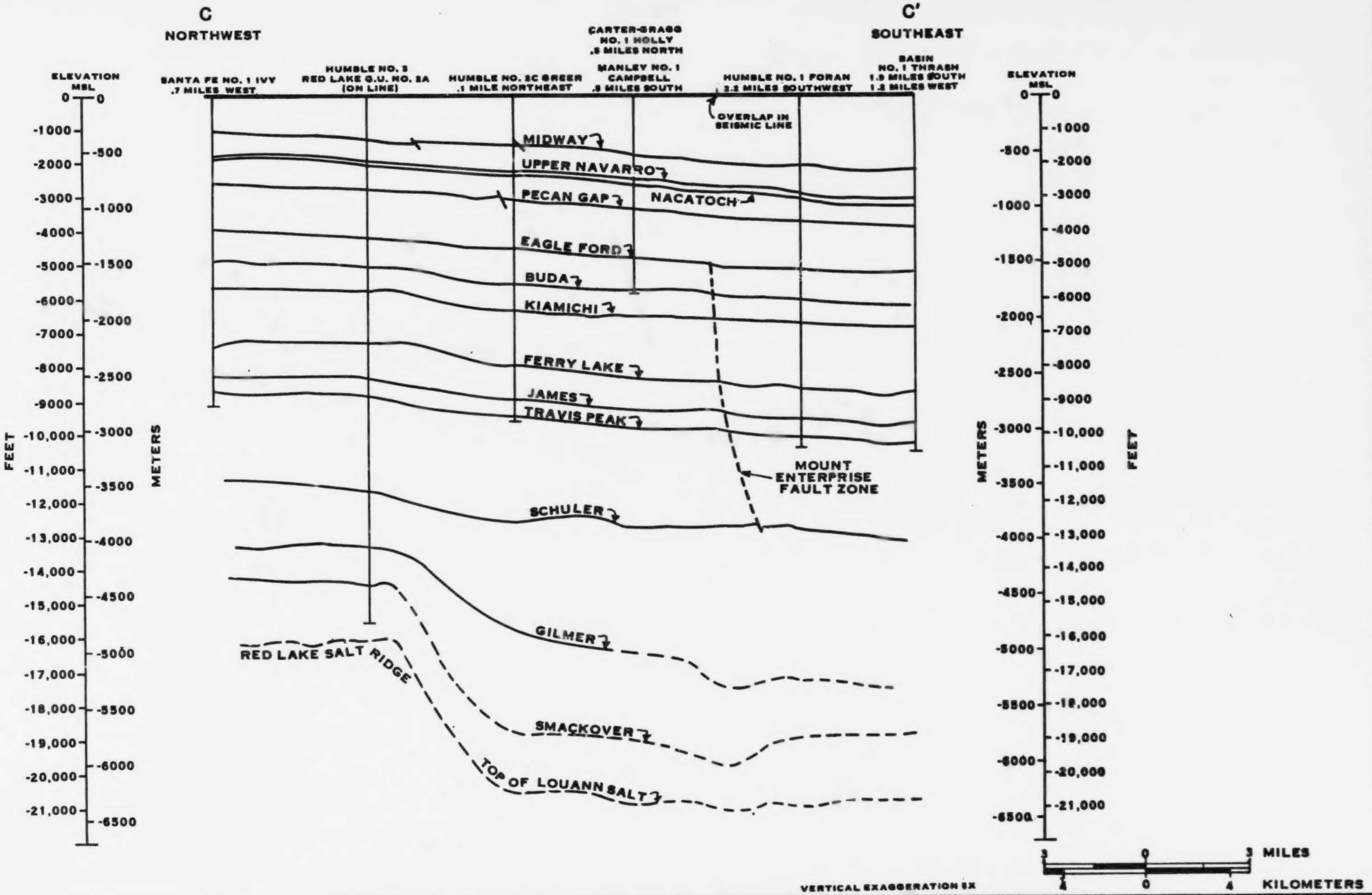
The Mt. Enterprise Fault Zone consists of a series of parallel normal faults, arcuate toward the Gulf Coast, which trend generally southwesterly from the western flank of the Sabine Uplift into the southeastern portion of the study area. The Mt. Enterprise Fault Zone structural characteristics are described below under Faulting (see 6.2.3.2.2).

The East Texas Salt Basin is marked by a thickening of Mesozoic and Cenozoic sediments towards its center, with a variable thickness of Louánn Salt. The most significant structural elements within the study area are salt structures (both deep and shallow) and related faults.

6.2.3.1 Salt Structures: Differential loading of sediments on top of the gently dipping Louann Salt is believed to have initiated lateral salt movement during the Upper Jurassic (Halbouty, 1979). This lateral salt movement formed salt anticlines or ridges which warped and occasionally faulted the overlying sediments. Figure 6-9 shows the location of the anticlinal salt structures in the study area. The north-south trending ridge in the vicinity of the Red Lake Oil Field illustrates the local thickening of the salt bed (Figures 6-10 and 6-18). The Jurassic and Lower Cretaceous sediments generally thin over the crests of the salt ridges within the study area. Formation of salt pillow (anticlinal) structures is the first step in the development of salt domes (Trusheim, 1960). Salt dome growth is described in Section 2.2., Volume I.

Both deep pillow salt structures and shallow salt domes are present in the study area. Their locations are shown in Figure 6-9. The deep Elkhart and Slocum Salt Domes (Figure 6-9) are associated with graben structures, presumably a result of extension created by the emplacement of the salt. These deep domes, as well as others such as Red Lake and Fleeto, represent salt movement which caused arching of the overlying rocks.

Seven shallow piercement domes have been located by drilling and by gravity surveys in the study area (Figure 6-9). Regional gravity and well data (see Appendix) suggest that some salt structures are linked together at depth by salt ridges (Figure 6-9). Piercement domes are described as having penetrated overlying sediments before they were consolidated, and as having exextended for thousands of feet above the original salt bed. Structural depressions called rim synclines are typically developed peripheral to piercement domes where the beds above the


C
NORTHWEST
C'
SOUTHEAST
ELEVATION MSL
SANTA FE NO. 1 IVY .7 MILES WEST
HUMBLE NO. 3 RED LAKE G.U. NO. 2A (ON LINE)
HUMBLE NO. 2C GREER .1 MILE NORTHEAST
CARTER-GRAGG NO. 1 HOLLY .5 MILES NORTH
MANLEY NO. 1 CAMPBELL .5 MILES SOUTH
HUMBLE NO. 1 FORAN 2.2 MILES SOUTHWEST
BASIN NO. 1 THRASH 1.9 MILES SOUTH 1.2 MILES WEST
OVERLAP IN SEISMIC LINE
MIDWAY
UPPER NAVARRO
PECAN GAP
NACATOCH
EAGLE FORD
BUDA
KIAMICHI
FERRY LAKE
JAMES
TRAVIS PEAK
SCHULER
MOUNT ENTERPRISE FAULT ZONE
GILMER
RED LAKE SALT RIDGE
SMACKOVER
TOP OF LOUANN SALT
FEET
METERS
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-12,000
-13,000
-14,000
-15,000
-16,000
-17,000
-18,000
-19,000
-20,000
-21,000
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000
-6500
VERTICAL EXAGGERATION 8X
3
0
3
MILES
4
0
4
KILOMETERS

LEGEND

STRATIGRAPHIC HORIZON
DASHED WHERE INFERRED ONLY FROM SEISMIC DATA

FAULT, DASHED WHERE INFERRED

LABELS INDICATE TOPS OF ONLY THOSE STRATIGRAPHIC HORIZONS WHICH CORRESPOND TO SEISMIC REFLECTORS

LOCATION OF LINE SHOWN IN FIGURE 6-3

PREPARED	QA	DATE	9/15/80
REVISED	GHF	DATE	11/9/81
REVISED		DATE	
APPROVED		DATE	8/15/80

T-1462-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

CROSS SECTION C-C' BASED ON
SEISMIC AND WELL DATA

JOB NO. MV9600

FIGURE 6-18

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41

bedded salt subsided with the withdrawal of salt into the domal area (Halbouty, 1979). These depressions, with pronounced structural relief, caused an over-thickening of sediments deposited adjacent to the salt domes, thus accelerating upward salt movement.

Oakwood Salt Dome has a well-developed overhang occurring on all sides at an elevation of -305 to -1,524 meters (-1,000 to -5,000 ft) MSL. The top of the salt is 366 meters (1,200 ft) deep and is overlain by a 137-meter (450-ft) caprock. Above the caprock are Wilcox sediments; overlying them is the Carrizo Formation which is exposed at the surface. Many of the beds adjacent to the dome thicken and dip towards the dome, defining a large rim syncline to the southwest.

Keechi Salt Dome in plan view is elliptical with its long axis oriented north-south. In profile the dome tapers towards the surface. The salt, which has been encountered at a depth of 133 meters (435 ft), is overlain by a variable thickness of caprock. The oldest unit exposed at the surface is the Pecan Gap Formation of the Gulfian Taylor Group. Upper Cretaceous and Tertiary sediments generally thicken and dip away from the dome into rim synclines that have developed south and west of the dome (Figure 6-15).

Palestine Salt Dome also has an elliptical shape in plan view and generally tapers toward the surface in profile. The top of the salt is approximately 30 meters (100 ft) below the ground surface and is overlain by approximately 15 meters (50 ft) of caprock. The oldest rocks exposed at the surface are those of the Comanchean, Washita Group, Buda Formation. Beds at the surface dip steeply off the flanks of the dome, forming a concentric outcrop pattern. Radial faulting is recognized in the surface beds (Figure 6-7) as well as in the subsurface adjacent to the dome.

Butler Salt Dome is circular in plan view and tapers slightly toward the surface. Salt has been encountered at a depth of 95 meters (312 ft), and no caprock has been reported. A bulge is developed on all sides of the dome to a depth of approximately 2,438 meters (8,000 ft). Shallow sediments dip steeply (up to 70 degrees) and thicken away from the dome into large rim synclines developed on the north and south sides of the dome.

Bethel Salt Dome is circular in plan view and has a well-developed overhang on all sides of the dome (extending down to a depth of 1,524 meters (5,000 ft). (See Figure 6-9 for dome location.) The depth to the top of the salt is approximately 457 meters (1,500 ft), and 122 meters (400 ft) of caprock is present. A rim syncline is developed around the periphery of the dome (Figure 6-16).

Concord Salt Dome is nearly circular in plan view and tapers toward the surface in profile. The salt is approximately 1,829 meters (6,000 ft) below the surface and no caprock has been encountered. Limestone of the Washita Group directly overlies the dome. The effects of domal uplift are recognized in subsurface units as young as upper Midway, approximately 1,219 meters (4,000 ft) above the dome. Most units generally thin slightly over the dome and thicken off the flanks.

Brushy Creek Dome is circular in plan view according to interpretation of gravity data. Salt has been encountered at a depth of 783 meters (2,570 ft) below the surface, and 15 meters (50 ft) of caprock is present. The doming action has uplifted beds above the salt mass, affecting beds as young as the Upper Cretaceous Ector Formation.

6.2.3.2 Faulting: Faulting in the study area was principally related to salt movement. Major concentrations of faults occurred above and adjacent to the salt ridge structures. The age and amount of displacement along the faults correspond to the timing and magnitude of the salt movement. Faults related to shallow piercement salt domes usually extend to or near the surface, while faults caused by deep salt structures generally die out before reaching the surface. This condition indicates that faulting tends to stop soon after domal emplacement ceases.

6.2.3.2.1 Supradomal and Other Local Faulting - Normal faulting is generally associated with shallow piercement salt domes because of the extensional forces exercised upon the overlying beds. These faults generally extend to the surface and commonly have a radial pattern as in Figure 6-7 for Palestine Dome. Graben structures also typically form over shallow domes (Halbouty, 1979) and are well developed over Keechi and Oakwood Domes.

Faults not directly related to shallow dome emplacement are also present in the study area. Major movement along these normal faults occurred during the Cretaceous (Figure 6-19), coinciding with the time of maximum salt movement. Most of the faults trend northeast-southwest, roughly paralleling the strike of the Cretaceous beds.

6.2.3.2.2 Mt. Enterprise Fault Zone - The Mt. Enterprise Fault Zone is one of the major controlling structural features of the East Texas Basin (Figure 6-17). It consists of a parallel series of displacements which mark the southeastern border of the East Texas Salt Basin. The fault system extends from a distance of about 129 km (80 mi) from the southwestern portion of the Sabine Uplift through the southern portion of the study area. The system apparently dies out before reaching the western border of the basin at the Mexia-Talco Fault Zone, about 32 km (20 mi) west of the study area. The dips of the Mt. Enterprise Fault planes at the surface range from about 30 to 60 degrees, with lower dips at depth. Stratigraphic displacements in Eocene beds at the surface (Midway and Claiborne) extended up to 152 meters (500 ft), increasing with depth to 213 meters (700 ft) in rocks of the Upper Cretaceous (Fisher, 1965).

Seismic data indicate that the fault system originated during the deposition of the Cotton Valley and Trinity Groups. The fault system is a series of graben structures resulting from extensional forces generated by subsidence in the Northeast Texas Embayment to the north and the Lower Gulf Coast Basin to the south. The graben structure can be traced across the study area using cross sections prepared from seismic and well data in the vicinity of the fault zone (see Appendix). The configuration of the fault zone is illustrated from east to west by the following

46

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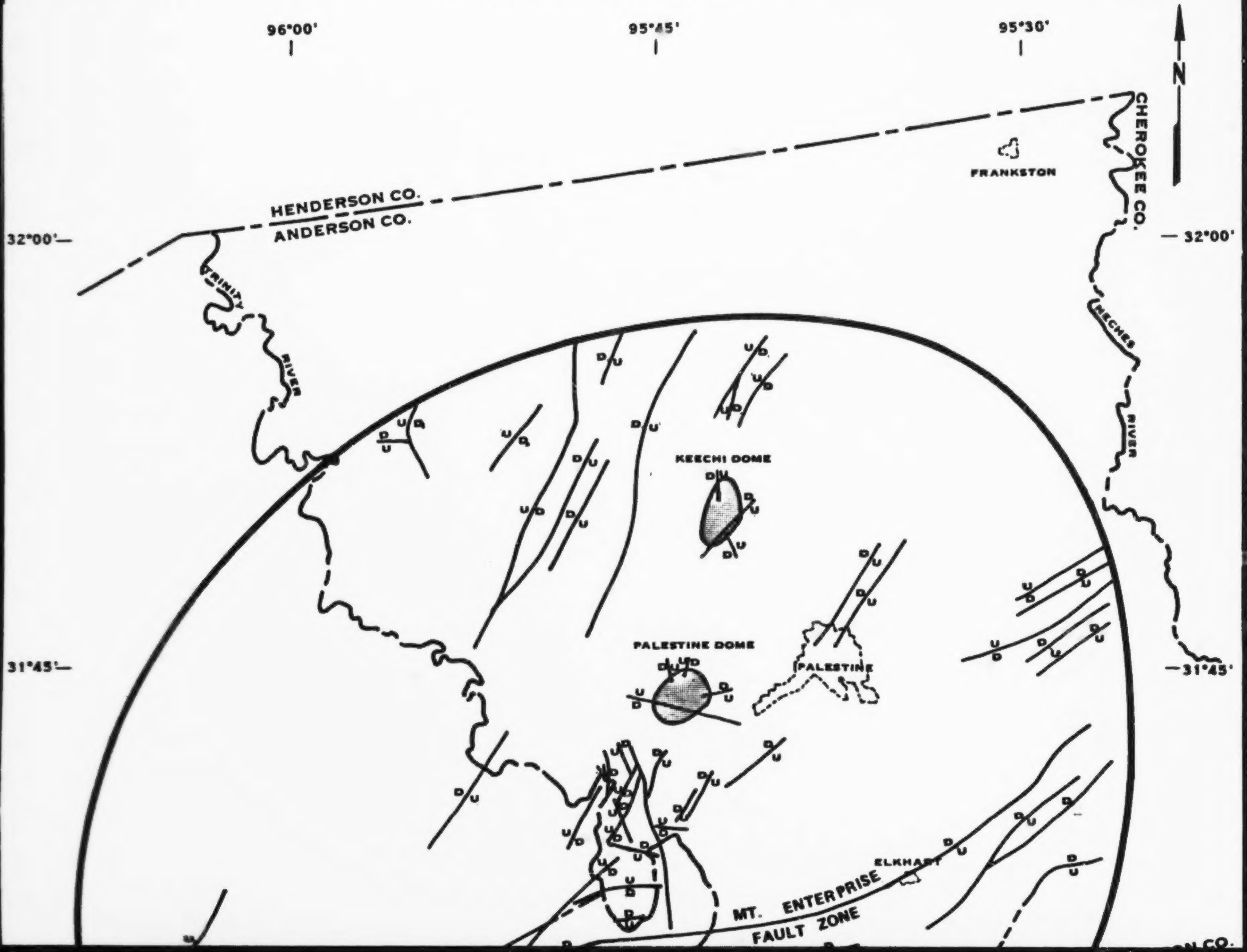
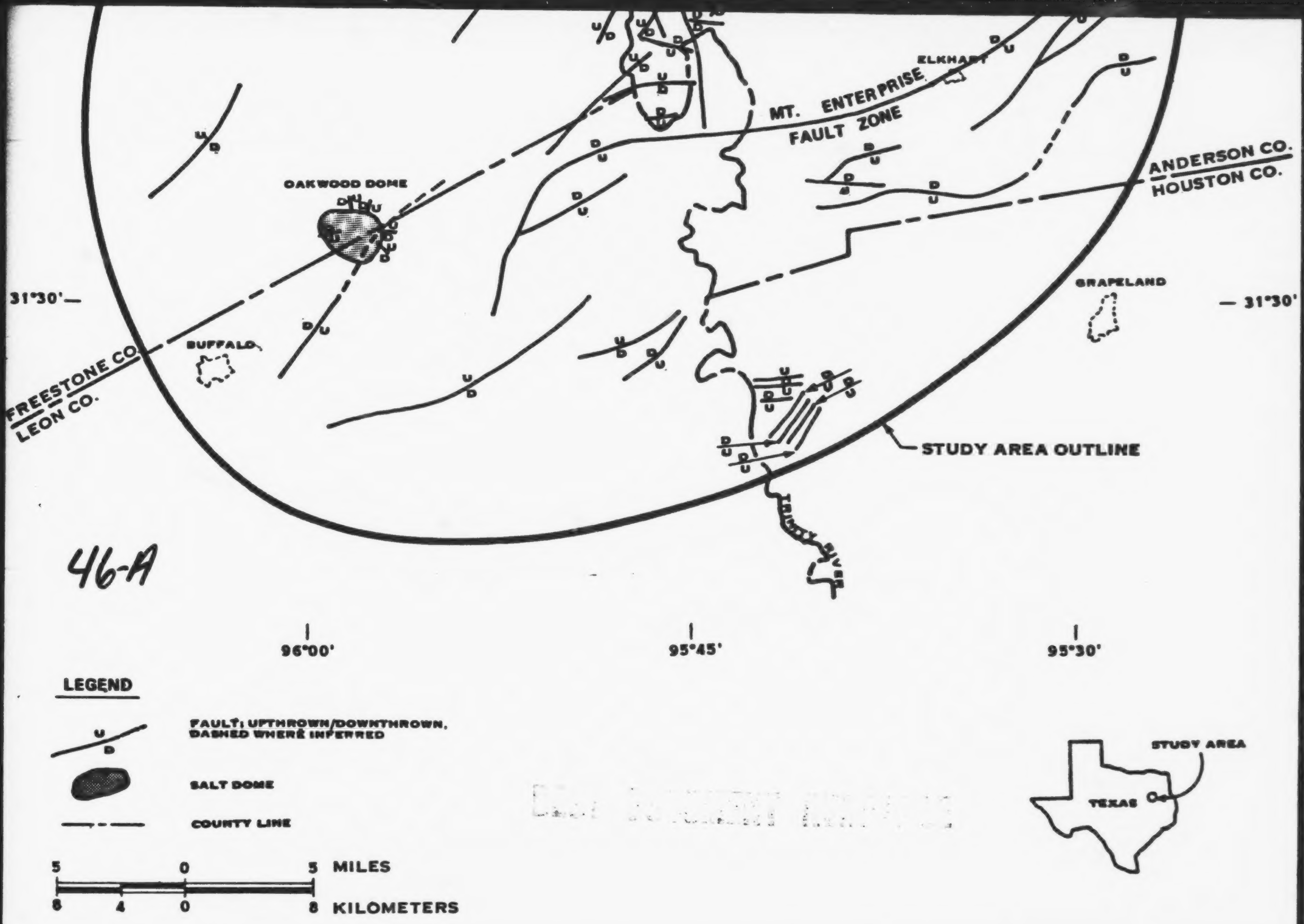

96°00'
95°45'
95°30'
N
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
32°00'
32°00'
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
31°45'
31°45'
ELKHART
MT. ENTERPRISE FAULT ZONE
U
D


MT. ENTERPRISE
FAULT ZONE
ELKHART
OAKWOOD DOME
ANDERSON CO.
HOUSTON CO.
FREESTONE CO.
LEON CO.
BUFFALO
GRAPELAND
TRINITY RIVER
STUDY AREA OUTLINE
31°30'
31°30'
96°00'
95°45'
95°30'
U
D
LEGEND
FAULT; UPTHROWN/DOWNTHROWN, DASHED WHERE INFERRED
SALT DOME
COUNTY LINE
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS

46-A

PREPARED *JH*	DATE *8/15/80*
REVISED *GHF*	DATE *11/9/81*
REVISED	DATE
APPROVED *[illegible]*	DATE *8/15/80*

T-1087-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
MAJOR FAULT TRENDS (ON CRETACEOUS HORIZONS)

JOB NO. MV9600

FIGURE 6-19

cross sections: D-D' (Figure 6-20), B-B' (Figure 6-11), E-E' (Figure 6-21), C-C' (Figure 6-18) and G-G' (Figure 6-22). Salt is usually present beneath the graben structures; however, the cause and effect relationship of the salt to faulting is not clearly understood.

The Mt. Enterprise Fault Zone developed in response to two mechanisms that occurred during different periods according to interpretation of seismic reflection and well control data. Initiation and growth of the fault system is postulated in the following sequence:

(1) Initial differential loading of post-Louann sediments mobilized salt from the main center of deposition southward to the present position of the fault system, forming a linear salt ridge, possibly resulting from pillowing inferred from regional gravity data and the position of Elkhart and Slocum Domes (Kreitler and others, 1980).

(2) Faulting, as illustrated by Cross Section D-D' (Figure 6-20), which apparently occurred during the Upper Jurassic, was the principal structural adjustment to the continuing salt buildup.

(3) Maximum movement occurred in the early Tertiary during Wilcox deposition, as indicated by the appreciable thickening of sediments on the downthrown (south) side of the Mt. Enterprise Fault where Early Tertiary centers of deposition were located.

(4) Subsidence in the Northeast Texas Embayment to the north and the Gulf Coast Basin to the south caused the fault zone to function as a hinge line and accelerated the movement of salt.

(5) As centers of deposition migrated farther south, stresses lessened and movement along the fault zone diminished.

Cessation of significant movement was apparently no later than Pliocene. Previous geologic mapping in the vicinity has shown no faulting in Quaternary age terrace deposits.

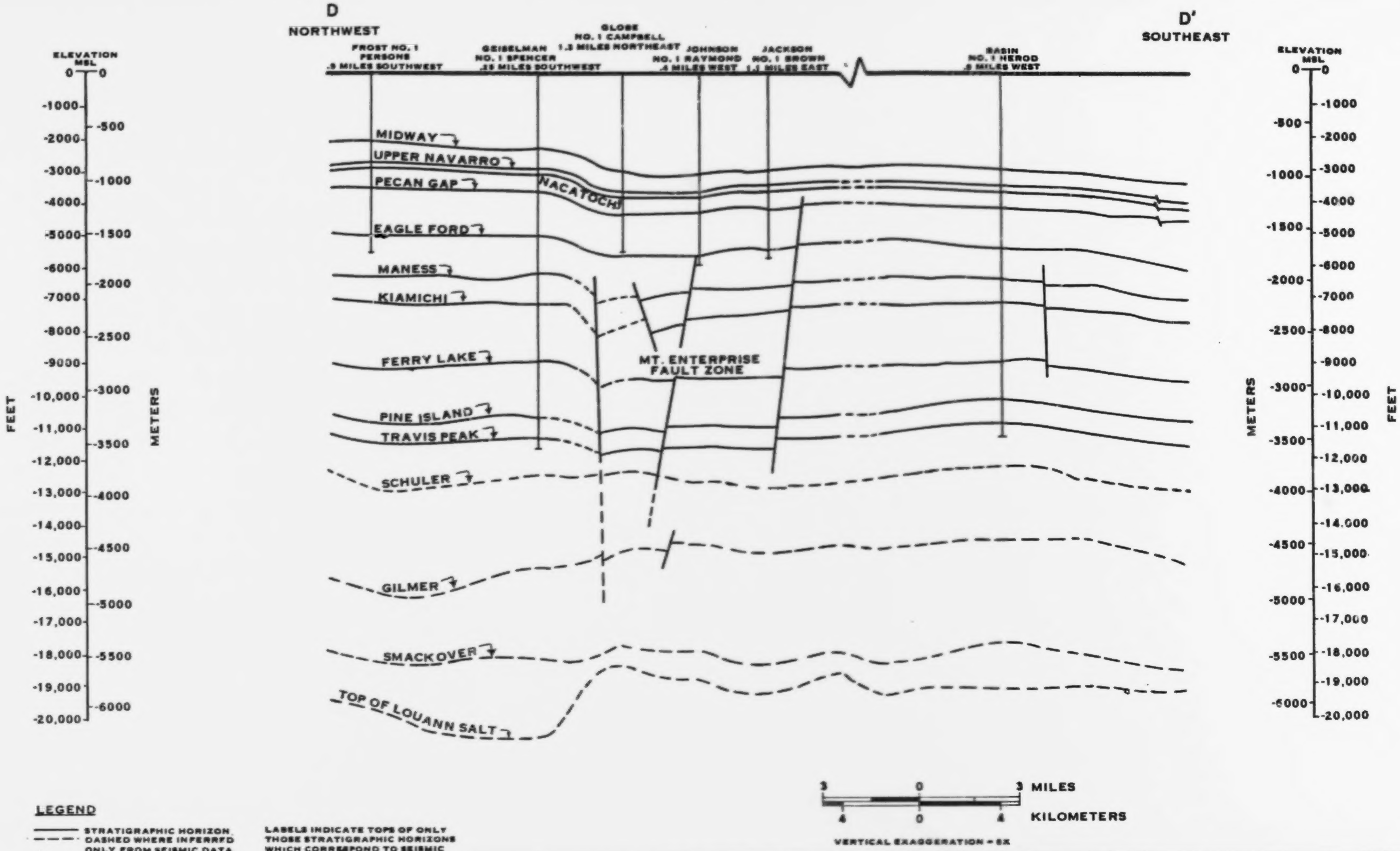
However, BEG (Collins and others, 1980) recently postulated minor Quaternary faulting in terrace deposits along the Trinity River in the study area, west of the westernmost surface expression of the Mt. Enterprise Fault Zone (Figure 6-23).

The exposure along the Trinity River shows:

(1) Two down-to-the-coast faults with a third compensating up-to-the-coast fault in Tertiary sediments, with cumulative displacement of 533, 229, and 660 mm (21, 9, and 26 in) (Figure 6-24)

(2) A Pleistocene terrace deposit overlying the Tertiary beds, estimated at 37,000 years in age, in which the basal sands and gravel are reported to have a cumulative vertical displacement of 152 mm (6 in) over a horizontal distance of 0.6 meters (2 ft)

(3) Supporting evidence of faulting in the basal terrace beds by multiple shear planes and step faults where flexuring of the unit occurs (Collins and others, 1980).


D
NORTHWEST
D'
SOUTHEAST
FROST NO. 1 PERSONS .9 MILES SOUTHWEST
GEISELMAN NO. 1 SPENCER .25 MILES SOUTHWEST
GLOBE NO. 1 CAMPBELL 1.3 MILES NORTHEAST
JOHNSON NO. 1 RAYMOND .4 MILES WEST
JACKSON NO. 1 BROWN 1.1 MILES EAST
BASIN NO. 1 HEROD .9 MILES WEST
ELEVATION MSL
FEET
METERS
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-12,000
-13,000
-14,000
-15,000
-16,000
-17,000
-18,000
-19,000
-20,000
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000
MIDWAY
UPPER NAVARRO
PECAN GAP
NACATOCH
EAGLE FORD
MANESS
KIAMICHI
FERRY LAKE
MT. ENTERPRISE FAULT ZONE
PINE ISLAND
TRAVIS PEAK
SCHULER
GILMER
SMACKOVER
TOP OF LOUANN SALT
3 0 3 MILES
4 0 4 KILOMETERS
VERTICAL EXAGGERATION = 5X

LEGEND

— STRATIGRAPHIC HORIZON
- - - DASHED WHERE INFERRED ONLY FROM SEISMIC DATA

\ FAULT, DASHED WHERE INFERRED.

LABELS INDICATE TOPS OF ONLY THOSE STRATIGRAPHIC HORIZONS WHICH CORRESPOND TO SEISMIC REFLECTORS

LOCATION OF LINE SHOWN IN FIGURE 6-3

PREPARED		DATE	2/15/80
REVISED	GHF	DATE	11/9/81
REVISED		DATE	
APPROVED		DATE	[illegible]

T-1037-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

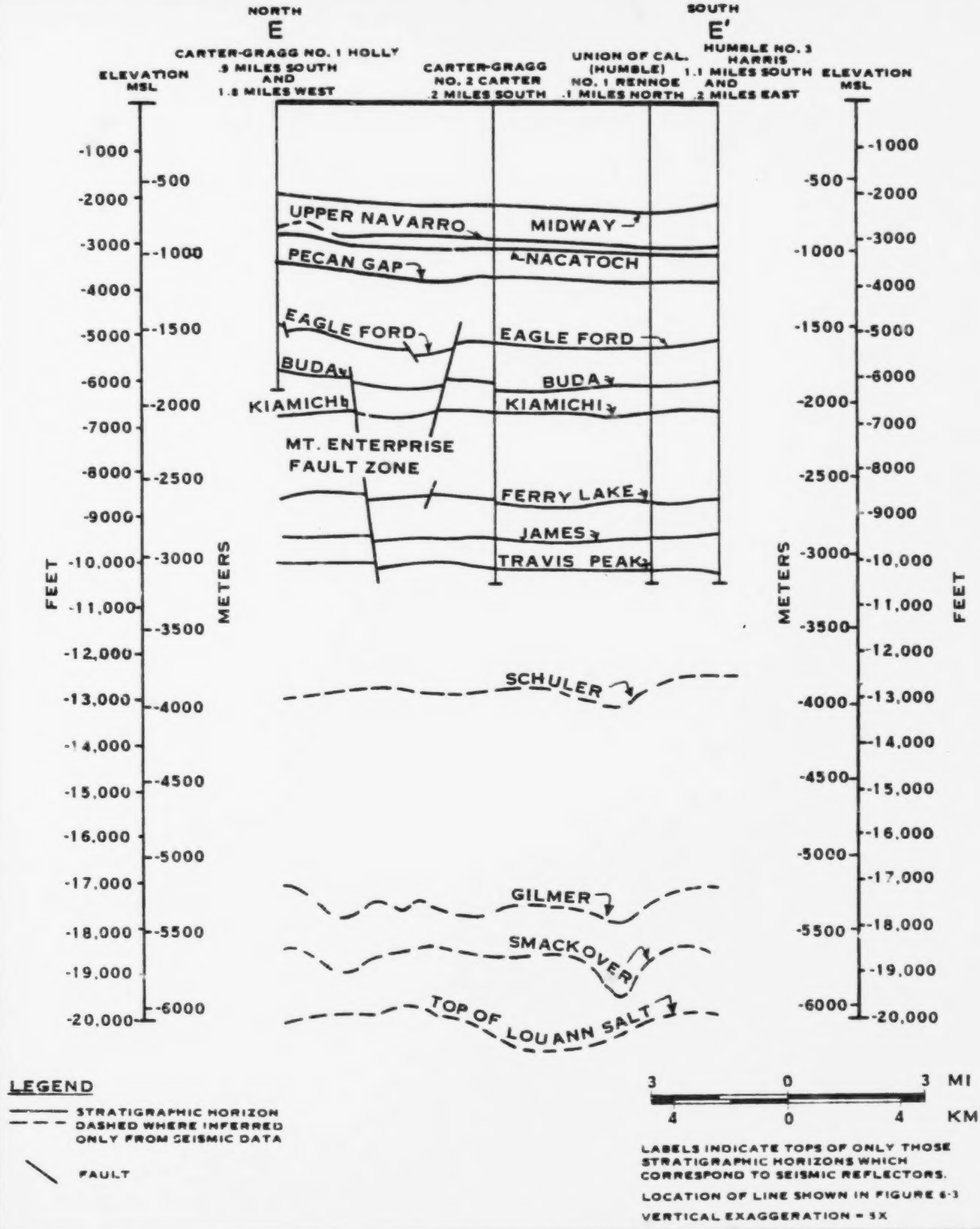
CROSS-SECTION D-D'
BASED ON SEISMIC AND WELL DATA

JOB NO. MV9600

FIGURE 6-20

BEST DOCUMENT AVAILABLE

AF 12338A


NORTH
E
SOUTH
E'
CARTER-GRAGG NO. 1 HOLLY
.9 MILES SOUTH
AND
1.8 MILES WEST
CARTER-GRAGG
NO. 2 CARTER
.2 MILES SOUTH
UNION OF CAL.
(HUMBLE)
NO. 1 RENNOE
.1 MILES NORTH
HUMBLE NO. 3
HARRIS
1.1 MILES SOUTH
AND
.2 MILES EAST
ELEVATION
MSL
FEET
METERS
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-12,000
-13,000
-14,000
-15,000
-16,000
-17,000
-18,000
-19,000
-20,000
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000
UPPER NAVARRO
MIDWAY
PECAN GAP
NACATOCH
EAGLE FORD
EAGLE FORD
BUDA
BUDA
KIAMICHI
KIAMICHI
MT. ENTERPRISE
FAULT ZONE
FERRY LAKE
JAMES
TRAVIS PEAK
SCHULER
GILMER
SMACKOVER
TOP OF LOUANN SALT
LEGEND
STRATIGRAPHIC HORIZON
DASHED WHERE INFERRED
ONLY FROM SEISMIC DATA
FAULT
3
0
3
MI
4
0
4
KM

LABELS INDICATE TOPS OF ONLY THOSE STRATIGRAPHIC HORIZONS WHICH CORRESPOND TO SEISMIC REFLECTORS.

LOCATION OF LINE SHOWN IN FIGURE 6-3

VERTICAL EXAGGERATION = 5X

PREPARED	DATE
REVISED GHF	DATE 11/9/81
REVISED	DATE
APPROVED	DATE [illegible]

T-1458-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM

GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

CROSS-SECTION E-E' BASED ON SEISMIC AND WELL DATA

JOB NO. MV9600

FIGURE 6-21

50

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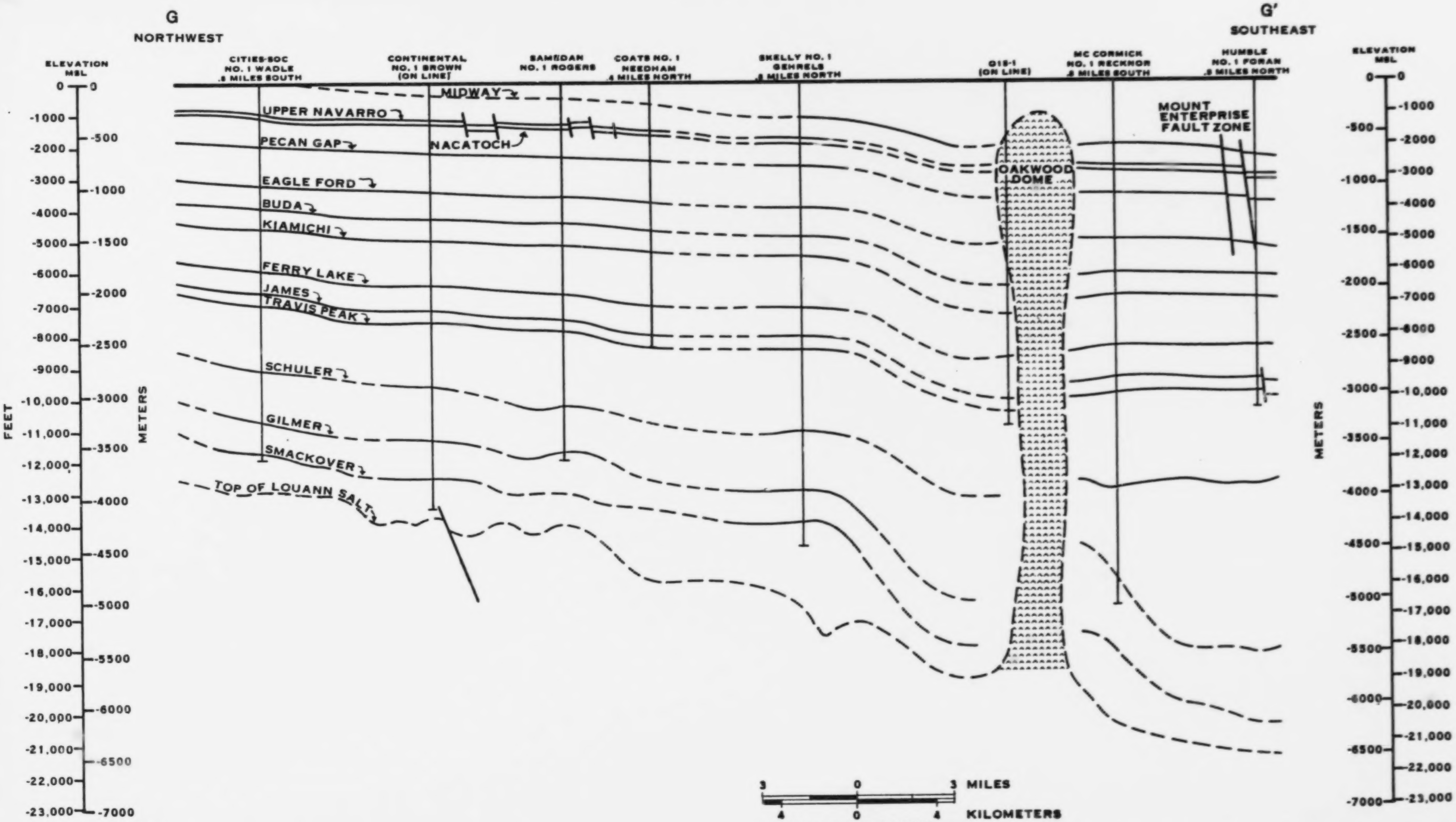
G
NORTHWEST
G'
SOUTHEAST
ELEVATION MSL
CITIES-SOC NO. 1 WADLE .8 MILES SOUTH
CONTINENTAL NO. 1 BROWN (ON LINE)
SAMEDAN NO. 1 ROGERS
COATS NO. 1 NEEDHAM .4 MILES NORTH
SKELLY NO. 1 GEHRELS .8 MILES NORTH
O15-1 (ON LINE)
MC CORMICK NO. 1 RECKNOR .8 MILES SOUTH
HUMBLE NO. 1 FORAN .8 MILES NORTH
MIDWAY
UPPER NAVARRO
NACATOCH
PECAN GAP
EAGLE FORD
BUDA
KIAMICHI
FERRY LAKE
JAMES
TRAVIS PEAK
SCHULER
GILMER
SMACKOVER
TOP OF LOUANN SALT
OAKWOOD DOME
MOUNT ENTERPRISE FAULT ZONE
FEET
METERS
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-12,000
-13,000
-14,000
-15,000
-16,000
-17,000
-18,000
-19,000
-20,000
-21,000
-22,000
-23,000
-500
-1500
-2500
-3500
-4500
-5500
-6500
3 0 3 MILES
4 0 4 KILOMETERS

VERTICAL EXAGGERATION 5X
KEY TO NUMBERED WELL IN TABLE 7-1

LEGEND

— STRATIGRAPHIC HORIZON
- - - DASHED WHERE INFERRED ONLY FROM SEISMIC DATA
\ FAULT

LABELS INDICATE TOPS OF ONLY THOSE STRATIGRAPHIC HORIZONS WHICH CORRESPOND TO SEISMIC REFLECTORS

LOCATION OF LINE SHOWN IN FIGURE 6-3

PREPARED _______ DATE 8/15/80
REVISED GHF DATE 11/9/81
REVISED _______ DATE _______
APPROVED _______ DATE 8/15/80

T-1080-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

CROSS-SECTION G-G' BASED ON SEISMIC AND WELL DATA

JOB NO. MV9600

FIGURE 6-22

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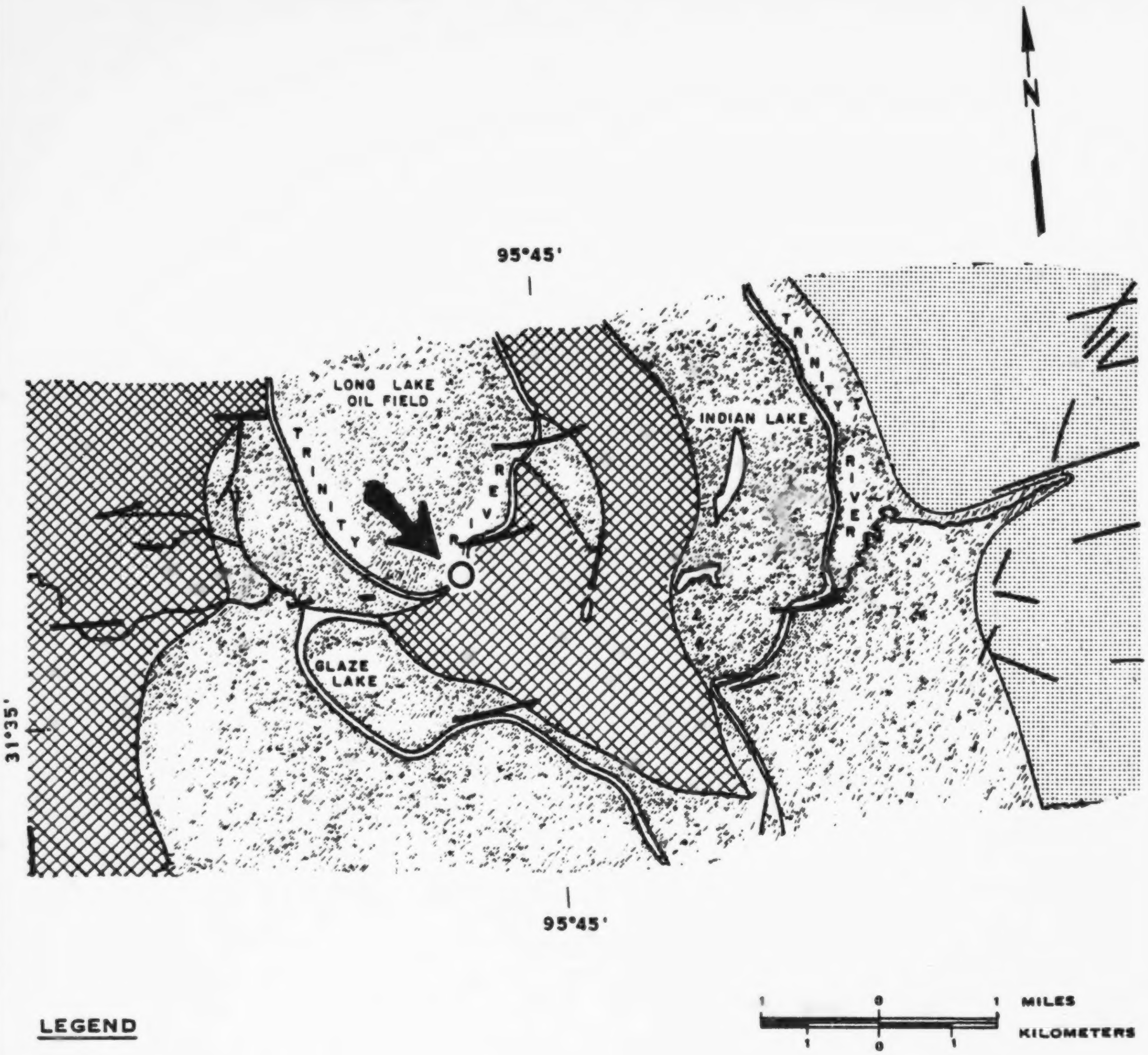

N
95°45'
LONG LAKE OIL FIELD
TRINITY RIVER
INDIAN LAKE
TRINITY RIVER
GLAZE LAKE
31°35'
31°35'
95°45'
1 0 1 MILES
1 0 1 KILOMETERS

LEGEND

▨ RECENT ALLUVIUM

▩ LATE PLEISTOCENE FLUVIATILE TERRACE DEPOSITS

░ EOCENE ROCKS UNDIFFERENTIATED

╲ LINEATION

➘ ○ LOCATION OF FAULT WITH DISPLACEMENT OF LATE PLEISTOCENE TERRACE DEPOSITS

REFERENCE

TBEG, 1980

PREPARED ____ DATE ____
REVISED ____ DATE ____
REVISED ____ DATE ____
APPROVED ____ DATE ____
T-1090-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

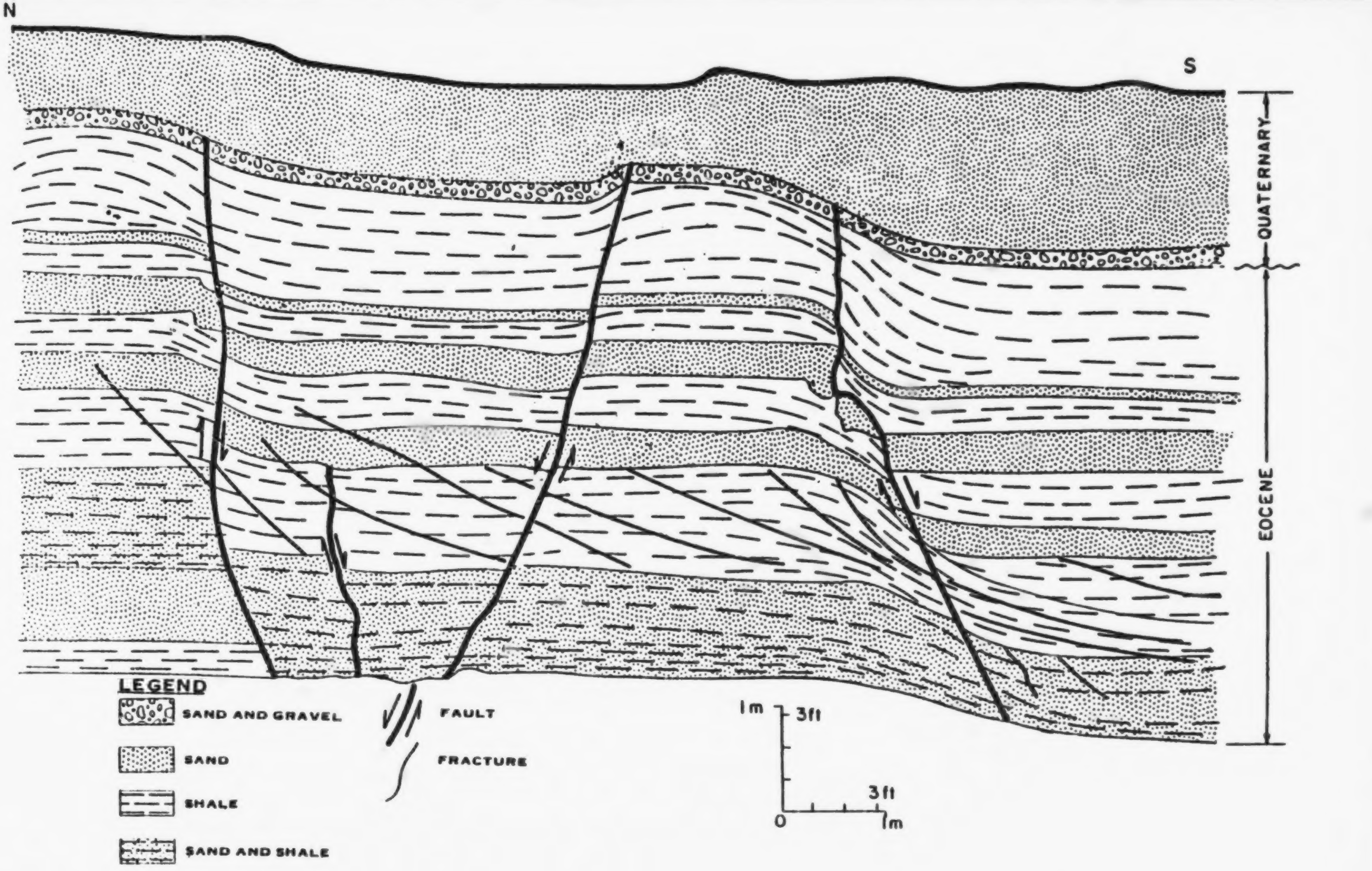
EAST TEXAS STUDY AREA
QUATERNARY FAULT LOCATION AND GEOLOGIC MAP

JOB NO. MV 9600 FIGURE 6-23

52

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE


N
S
QUATERNARY
EOCENE
LEGEND
SAND AND GRAVEL
SAND
SHALE
SAND AND SHALE
FAULT
FRACTURE
1m
3ft
0
3ft
1m

GEOLOGY FROM COLLINS AND OTHERS (1980)

PREPARED [illegible] DATE [illegible] REVISED GHF DATE 11/9/81 REVISED ____ DATE ____ APPROVED [illegible] DATE [illegible] T-1091-2	NATIONAL WASTE TERMINAL STORAGE PROGRAM GEOLOGIC EVALUATION GULF COAST SALT DOMES LAW ENGINEERING TESTING COMPANY MARIETTA, GEORGIA	EAST TEXAS STUDY AREA CROSS SECTION OF QUATERNARY FAULT AT OUTCROP JOB NO. MV9600 FIGURE 6-24

Displacements of 0.3 to 0.6 meters (1 to 2 ft) in the gravel unit were reported from examination of samples from auger holes a few hundred feet east of the river location (Collins and others, 1980). The postulated Quaternary activity will be discussed further in Section 6.2.5. The fault system has been extended in the subsurface west of the Trinity River (based on seismic data) where displacements decrease and the fault trends southwestward away from Oakwood Salt Dome (Figures 6-21, 6-18 and 6-22).

Regional gravity data indicate linear anomalies along the Mt. Enterprise Fault System, which could be genetically related to the faults. Linear anomalies have also been identified through regional gravity data in other parts of the study area. Such anomalies could indicate faulting, irregularities in the basement, or appreciable changes in the depositional dip. If the anomalies are related to basement faulting, it is not apparent in near-surface sediments reflected in a number of seismic lines crossing these anomalies. However, it is more likely that the gravity anomalies result from irregularities in the basement or steeper dips of the sediments above the basement, probably related to salt structures.

6.2.4 GEOLOGICAL HISTORY: Uplift and large-scale block faulting in the the mid-Triassic established the tectonic framework for the Northeast Texas Embayment and the study area. Following uplift, which had ceased by Late Triassic or Early Jurassic times, subsidence began and, by Upper Jurassic, normal marine waters flooded the region (Kehle, 1978). Marine circulation was restricted by the basin and range topography because of block faulting prior to the precipitation of the Louann evaporite sequence initiating the East Texas Basin along the axis of the Northeast Texas Embayment.

Basin development established the regional dip of the Jurassic and Lower Cretaceous units north of the Mt. Enterprise Fault Zone within the study area. The beds dip towards the north and northeast into the basin because of subsidence within the basin. South of the Mt. Enterprise Fault Zone the same beds dip generally southward into the Gulf Coast Basin. This suggests that the Northeast Texas Embayment might have been partially restricted from the Lower Gulf Coast Basin south of the study area during this time interval.

Deposition of the Late Jurassic Smackover Formation initiated salt movement in the underlying Louann Salt. Salt dome growth models are discussed in Volume I. Salt domes in the East Texas Salt Basin appear to have followed Trusheim (1960) and Loocke's (1978) model. Based on their model, Palestine, Butler, and Keechi Domes represent the truncation stage, and Oakwood and Bethel Domes represent the burial stage (Kreitler and others, 1980).

Salt dome growth, which began in the Late Jurassic, proceeded contemporaneously with sediment deposition through the Cretaceous. Growth continued until at least Eocene time, according to interpretations of seismic data which indicate warping and faulting of Eocene sediments above the domes.

By the end of the Cretaceous the regional dip of the beds became predominantly south and southeastward toward the Lower Gulf Coast Basin because of regional tilting, which shifted the centers of maximum deposition southward. The East Texas Basin was filled by Early Tertiary time and basinal subsidence ceased. The effect of continued subsidence in the Lower Gulf Coast Basin is demonstrated by the thickening of virtually all units of Upper Cretaceous and Tertiary sections toward the southeast.

Up to 5,791 meters (19,000 ft) of sediments was deposited during development of the Northeast Texas Embayment. Structural contour maps (Figures 6-26 through 6-32) demonstrate the relationships among sedimentary deposition, basin subsidence and salt movement. The maps were prepared by using available well data, and faulting is indicated only where it can be demonstrated by well control.

The structural contour maps show that the older sedimentary units, for example the Travis Peak and James, were affected more by basin subsidence than were younger units. This is illustrated by a general decrease in the structural relief upward in the section.

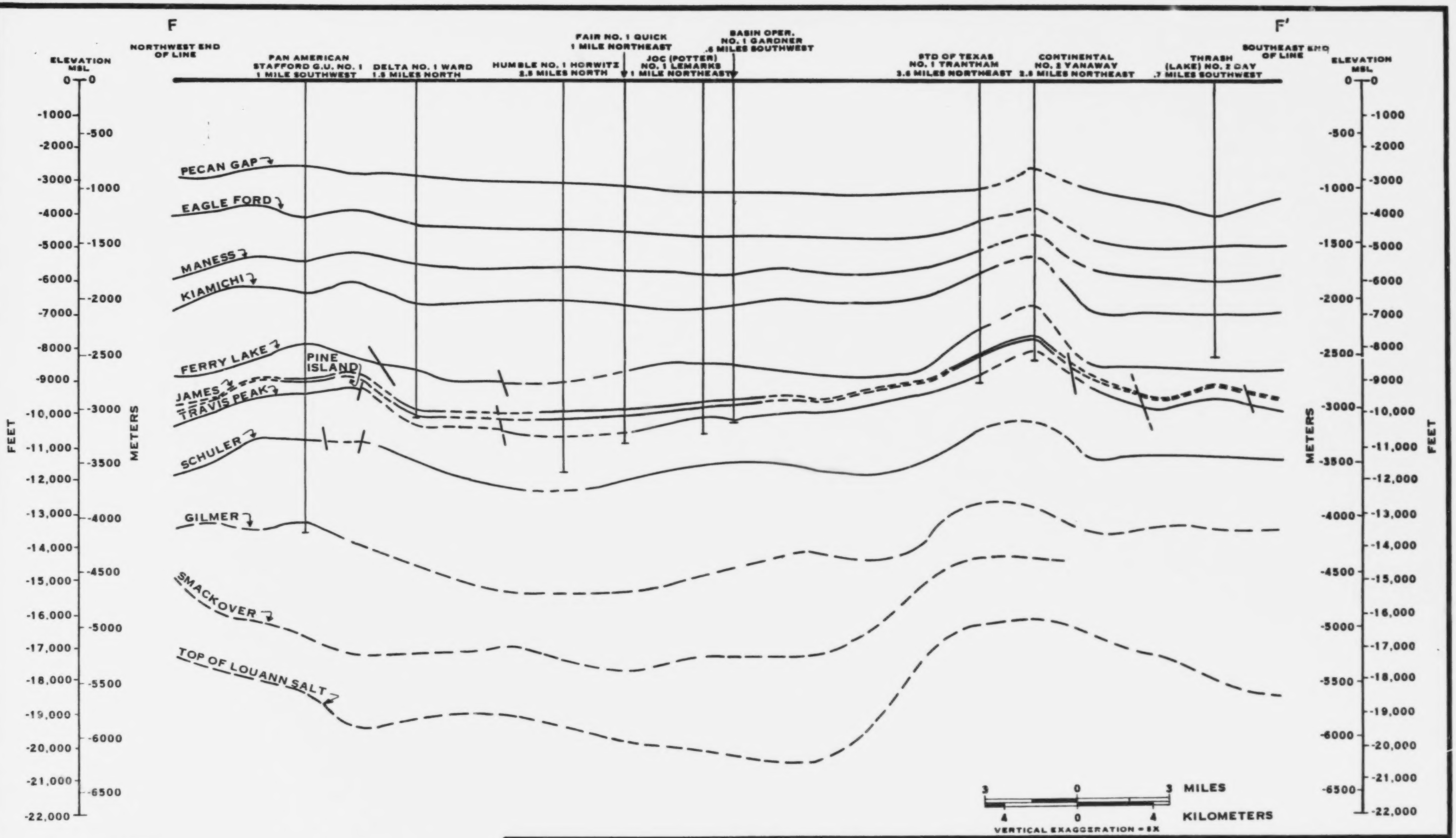
Three positive features defined by the structure maps are found along the east border, along the western portion, and in the southeastern portion of the study area. In the western portion of the study area the Travis Peak map shows a pronounced dip to the east (Figure 6-26). The older to younger sequence of units shows that the regional dip changed to a more southerly direction (Figure 6-26 through 6-32). By early Tertiary the regional dip had become predominantly south-southeasterly [shown in structure map top of Midway (Figure 6-32)].

The irregular surfaces defined by the structure contour maps of the different units are the result of salt movement. The area from the vicinity of Keechi and Palestine Domes southwestward to the Trinity River is generally a positive feature on the structure maps. On the other hand, Oakwood and Bethel Domes remained negative areas of continuing, though lessening, subsidence.

Claiborne Group sediments are the youngest Tertiary rocks present in the study area. The hiatus between the Claiborne Group and the overlying Quaternary fluvial deposits represents at least 35 million years (Table 6-1). During this time there was regional uplift, including the Northeast Texas Embayment, resulting in a cessation of sedimentation and subsequent erosion of existing beds.

6.2.5. EAST TEXAS AREA SEISMICITY: The methodology used to define the seismicity of the Interior Salt Basins has been described in detail in Section 2.5 (Volume I). The concept of seismotectonic regions, and its link to seismic risk analysis, was also thoroughly discussed in Section 2.5. Finally, an approach to seismic risk analysis was presented and preliminary conclusions were drawn concerning the seismicity of the Interior Salt Basins.

This section presents tectonic and seismic aspects which are specific to the East Texas Salt Basin and surrounding areas.


F
F'
NORTHWEST END OF LINE
SOUTHEAST END OF LINE
PAN AMERICAN STAFFORD G.U. NO. 1 1 MILE SOUTHWEST
DELTA NO. 1 WARD 1.5 MILES NORTH
HUMBLE NO. 1 HORWITZ 2.5 MILES NORTH
FAIR NO. 1 QUICK 1 MILE NORTHEAST
JOC (POTTER) NO. 1 LEMARKS 1 MILE NORTHEAST
BASIN OPER. NO. 1 GARDNER .6 MILES SOUTHWEST
STD OF TEXAS NO. 1 TRANTHAM 3.6 MILES NORTHEAST
CONTINENTAL NO. 2 YANAWAY 2.8 MILES NORTHEAST
THRASH (LAKE) NO. 2 DAY .7 MILES SOUTHWEST
ELEVATION MSL
FEET
METERS
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-12,000
-13,000
-14,000
-15,000
-16,000
-17,000
-18,000
-19,000
-20,000
-21,000
-22,000
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000
-6500
PECAN GAP
EAGLE FORD
MANESS
KIAMICHI
FERRY LAKE
PINE ISLAND
JAMES
TRAVIS PEAK
SCHULER
GILMER
SMACKOVER
TOP OF LOUANN SALT
3
0
3
MILES
4
0
4
KILOMETERS
VERTICAL EXAGGERATION = 8X

LEGEND

— STRATIGRAPHIC HORIZON
- - - DASHED WHERE INFERRED ONLY FROM SEISMIC DATA

\ FAULT, DASHED WHERE INFERRED.

LABELS INDICATE TOPS OF ONLY THOSE STRATIGRAPHIC HORIZONS WHICH CORRESPOND TO SEISMIC REFLECTORS

LOCATION OF LINE SHOWN IN FIGURE 6-3

PREPARED	[illegible]	DATE	8/13/80
REVISED	GHF	DATE	11/9/81
REVISED		DATE	
APPROVED	[illegible]	DATE	[illegible]

T-1079-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

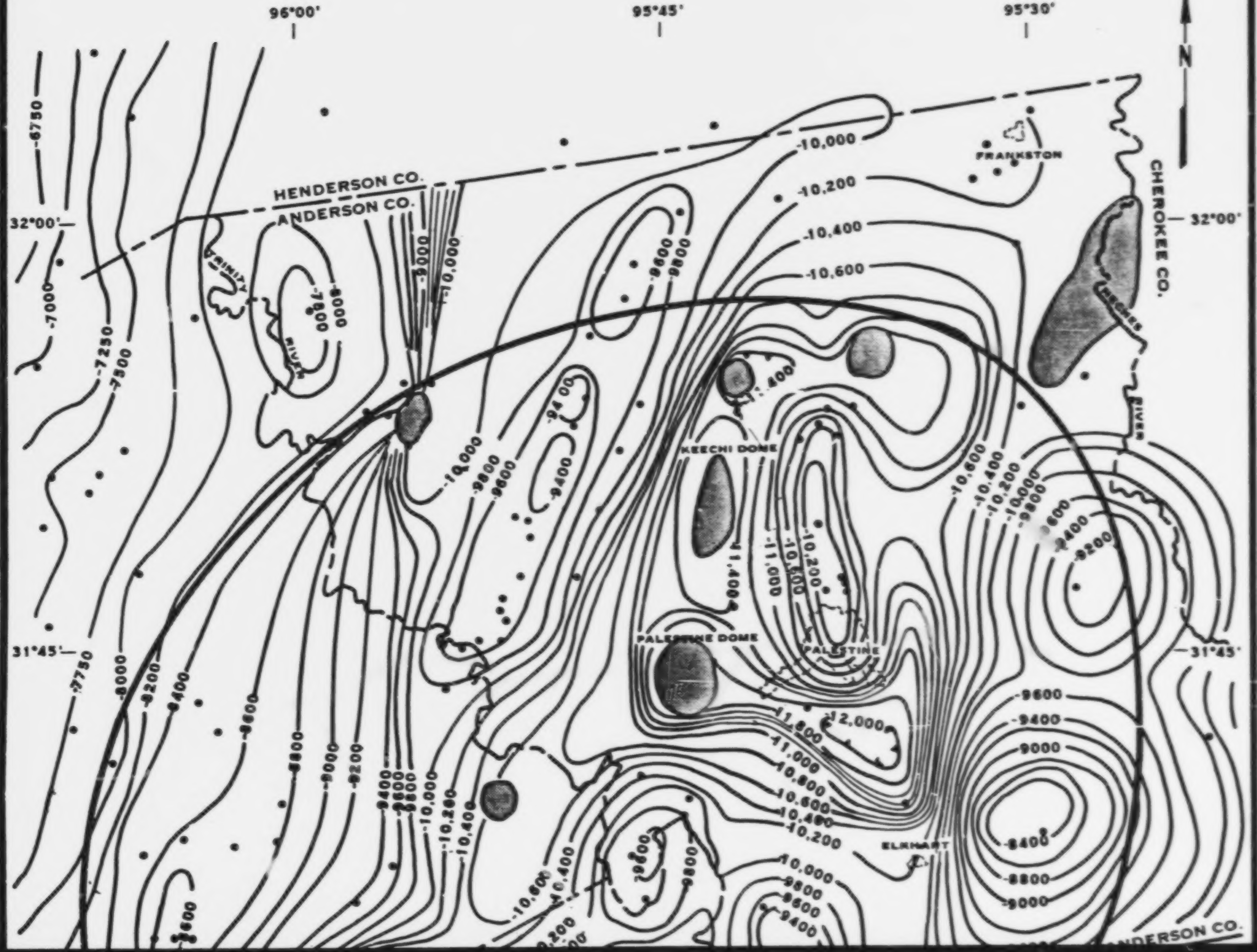
CROSS SECTION F-F' BASED ON SEISMIC AND WELL DATA

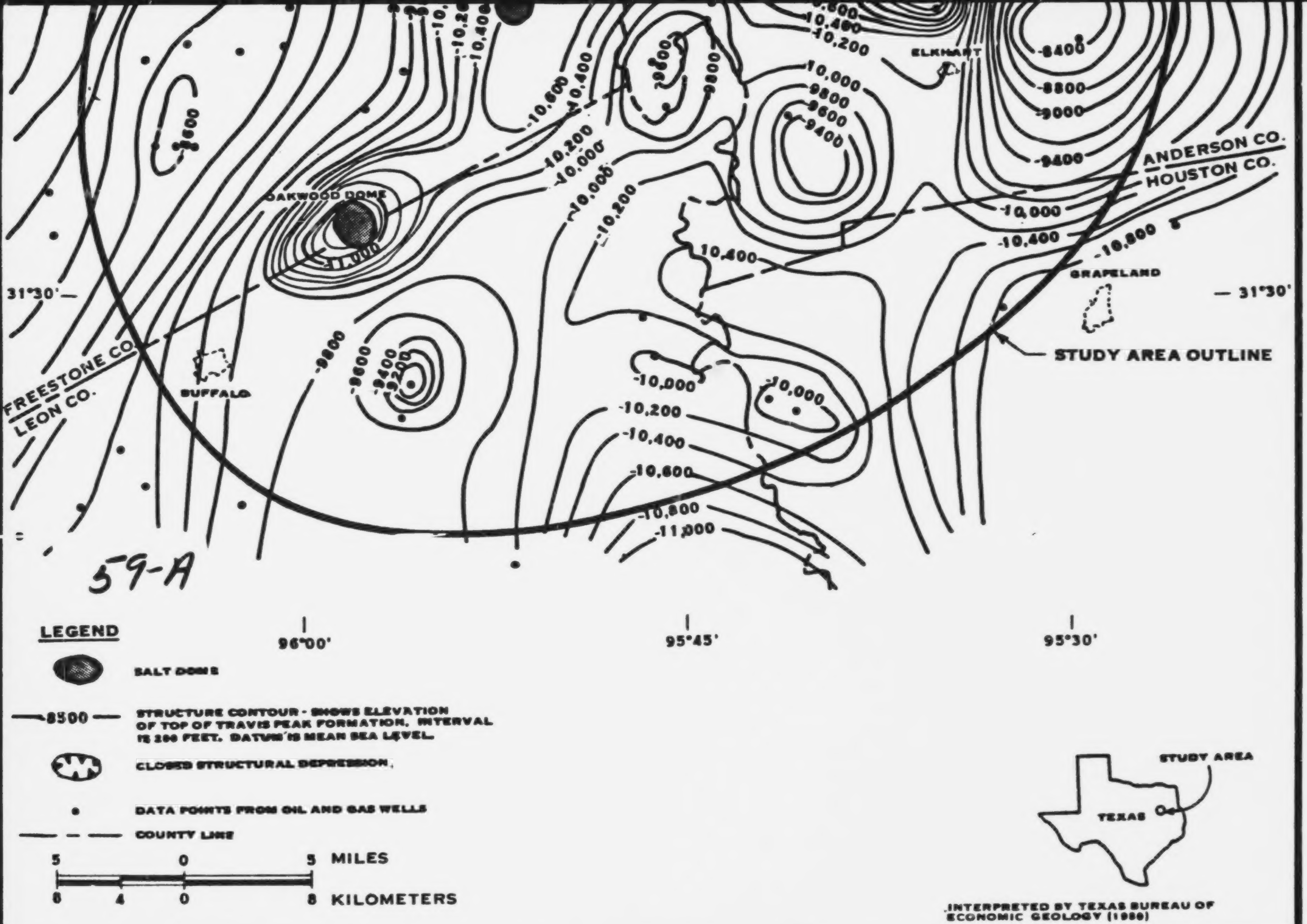
JOB NO. MV9600

FIGURE 6-25

58 BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE


96°00'
95°45'
95°30'
N
32°00'
31°45'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
-6750
-7000
-7250
-7500
-7750
-7800
-8000
-8200
-8400
-8600
-8800
-9000
-9200
-9400
-9600
-9800
-10,000
-10,200
-10,400
-10,600
-10,800
-11,000
-11,400
-11,800
-12,000
-9200
-8400
-8800


-10,400
-10,200
-10,600
-10,400
-10,200
-10,000
-10,000
-10,200
9600
9800
-9800
10,600
10,400
10,200
10,000
9800
9600
9400
ELKHART
-8400
-8800
-9000
-9400
ANDERSON CO.
HOUSTON CO.
-10,000
-10,400
-10,800
GRAPELAND
OAKWOOD DOME
-11,000
10,400
-9600
31°30'
31°30'
STUDY AREA OUTLINE
FREESTONE CO.
LEON CO.
BUFFALO
-9800
-9600
-9400
-9200
-10,000
-10,000
-10,200
-10,400
-10,600
-10,800
-11,000
96°00'
95°45'
95°30'
LEGEND
SALT DOME
-8500
STRUCTURE CONTOUR - SHOWS ELEVATION OF TOP OF TRAVIS PEAK FORMATION. INTERVAL IS 200 FEET. DATUM IS MEAN SEA LEVEL.
CLOSED STRUCTURAL DEPRESSION.
DATA POINTS FROM OIL AND GAS WELLS
COUNTY LINE
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS

59-A

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

PREPARED dH DATE 9/15/80
REVISED GHF DATE 11/9/81
REVISED ______ DATE ______
APPROVED TMF DATE 8/15/80
T-1081-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA . GEORGIA

EAST TEXAS STUDY AREA

STRUCTURE - TOP OF
TRAVIS PEAK FORMATION

JOB NO. MV9600

FIGURE 6-26

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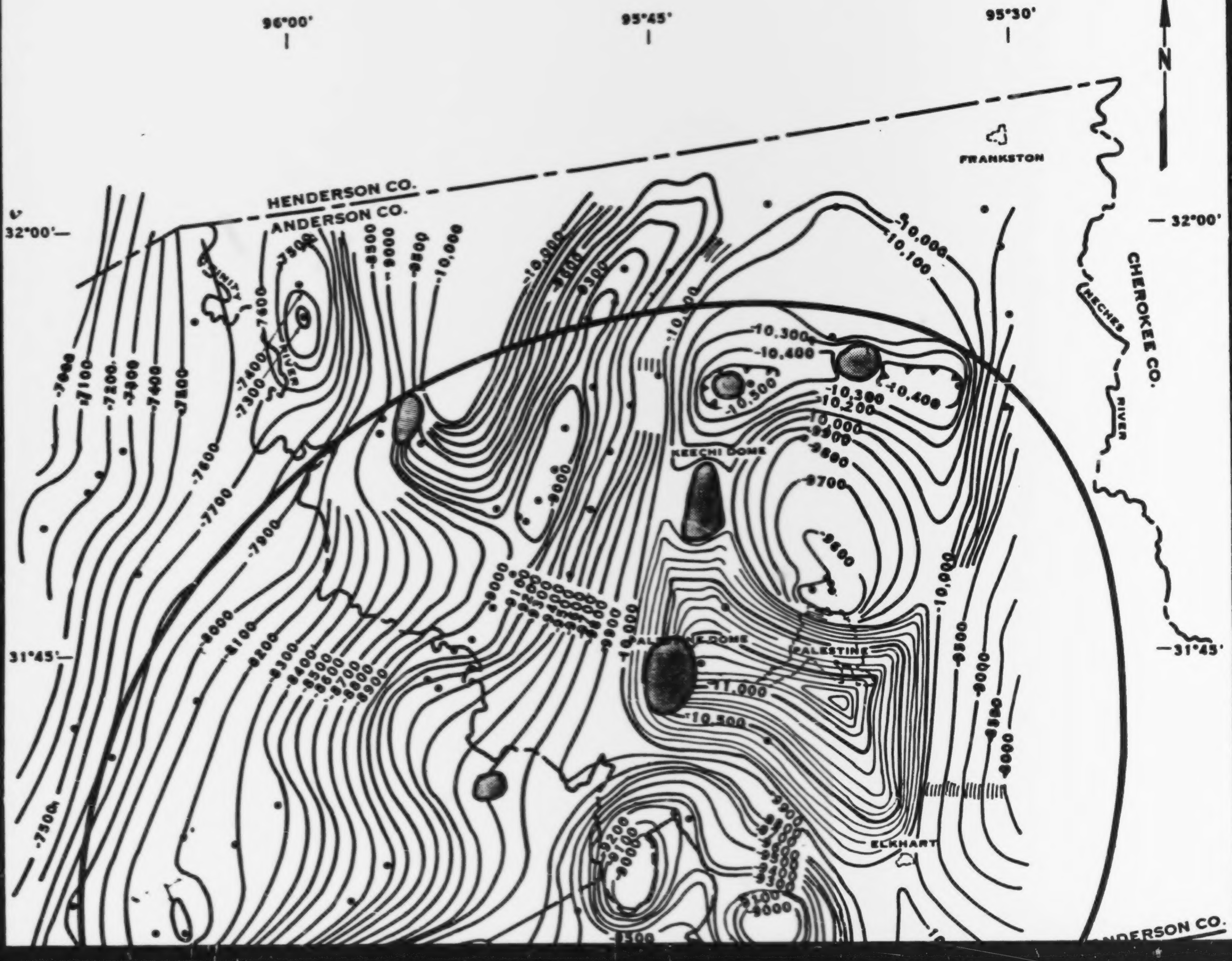
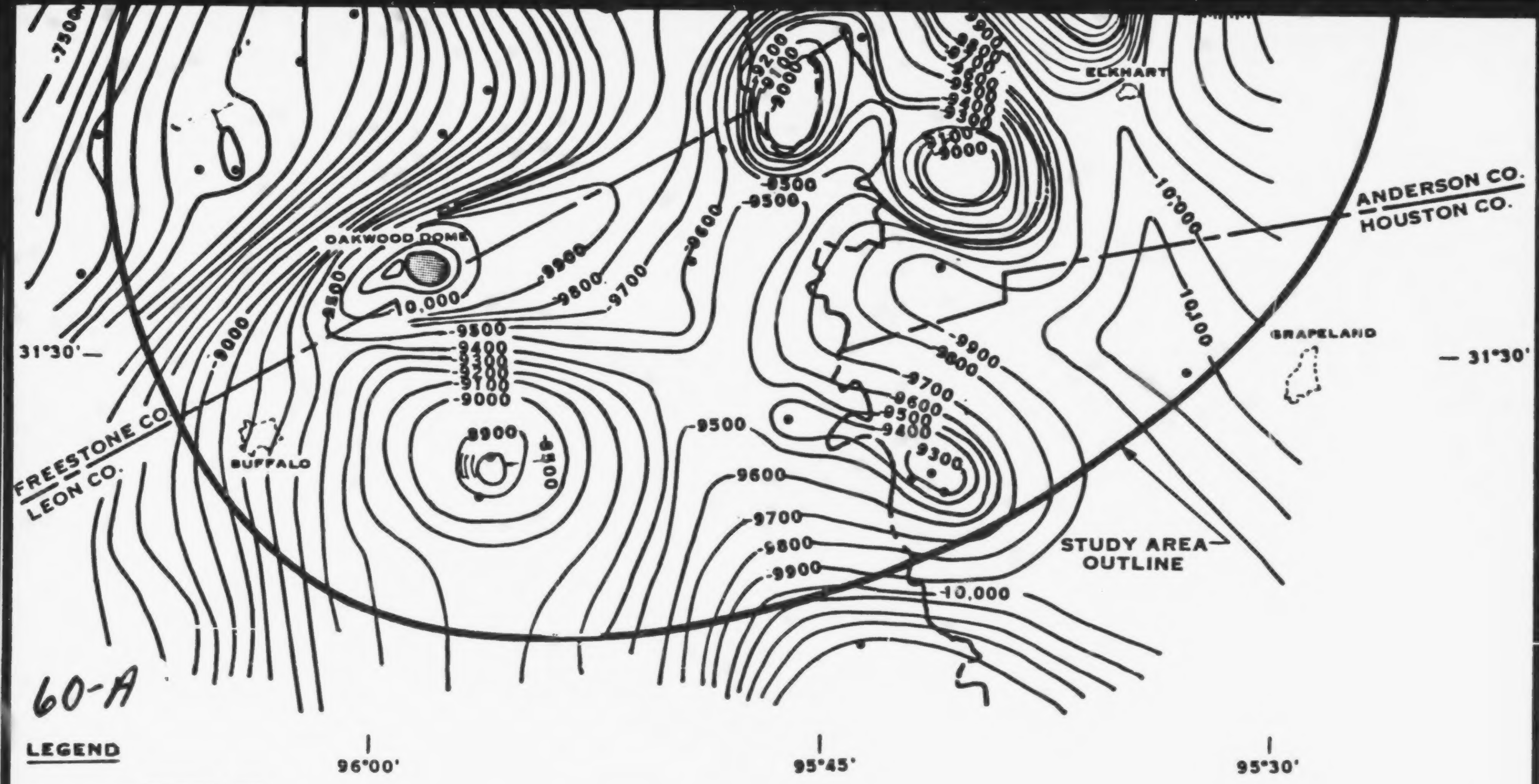

96°00'
95°45'
95°30'
N
32°00'
31°45'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
NECHES RIVER
TRINITY RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
ANDERSON CO.
-7000
-7100
-7200
-7300
-7400
-7500
-7600
-7700
-7800
-7900
-8000
-8100
-8200
-8300
-8400
-8500
-8600
-8700
-8800
-8900
-9000
-9500
-9700
-9800
-9900
-10,000
-10,100
-10,200
-10,300
-10,400
-10,500
-11,000


-7500
OAKWOOD DOME
ELKHART
ANDERSON CO.
HOUSTON CO.
FREESTONE CO.
LEON CO.
BUFFALO
GRAPELAND
31°30'
31°30'
-9000
-9500
-9600
-9700
-9800
-9900
-10,000
-9400
-9300
-9200
-9100
-8900
STUDY AREA OUTLINE
96°00'
95°45'
95°30'

60-A

LEGEND

COUNTY LINE

SALT DOME

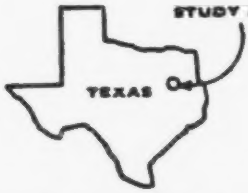
-9500 STRUCTURE CONTOUR - SHOWS ELEVATION OF TOP OF JAMES FORMATION, INTERVAL IS 100 FEET. DATUM IS MEAN SEA LEVEL.

CLOSED STRUCTURAL DEPRESSION.

● DATA POINTS FROM OIL AND GAS WELLS

5 0 5 MILES

8 4 0 8 KILOMETERS


STUDY AREA
TEXAS

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

PREPARED	DATE 9/15/80
REVISED GHF	DATE 11/9/81
REVISED	DATE
APPROVED	DATE 8/15/80

T-1082-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

STRUCTURE - TOP OF JAMES

JOB NO. MV9600

FIGURE 6-27

61

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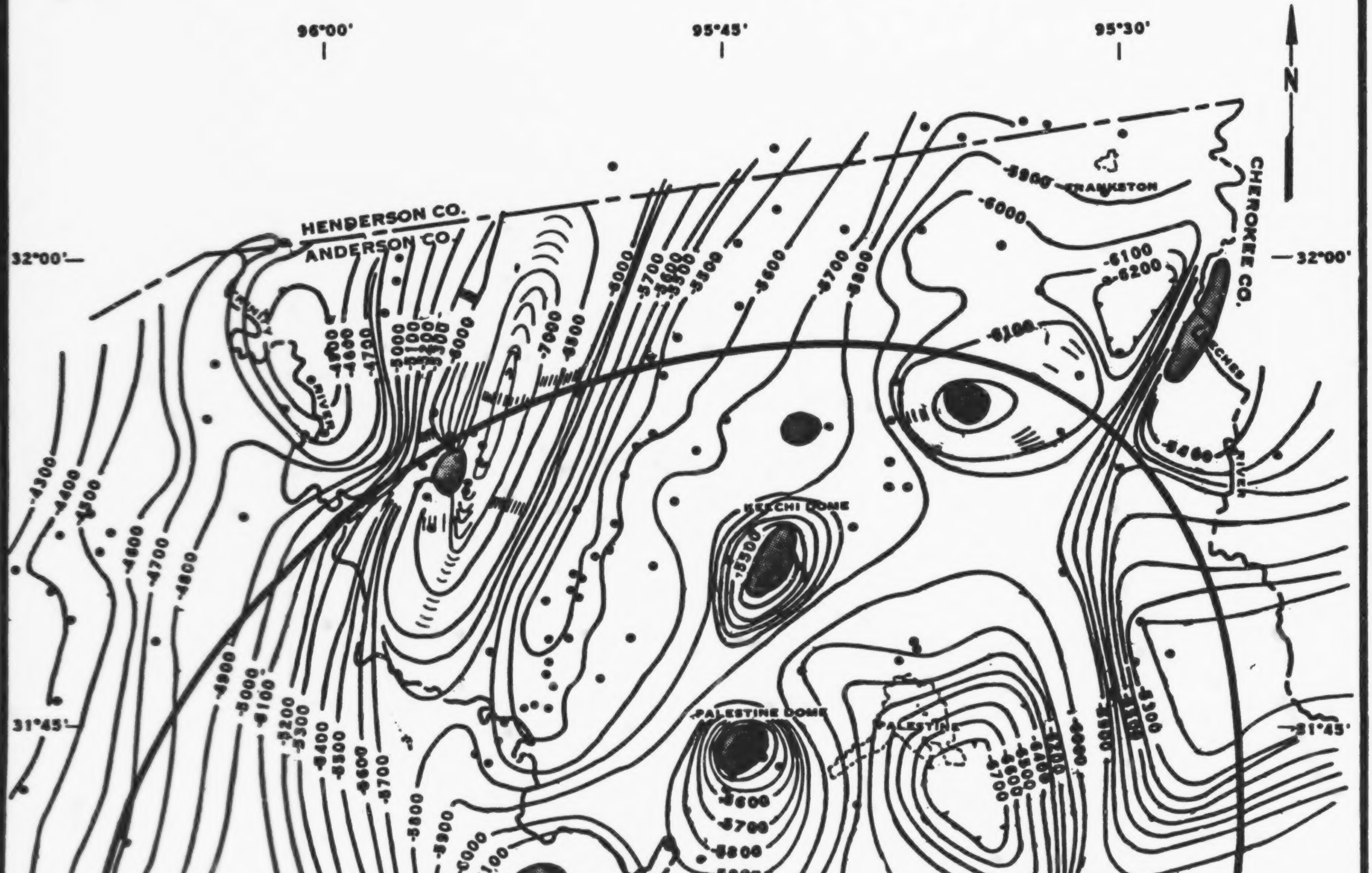
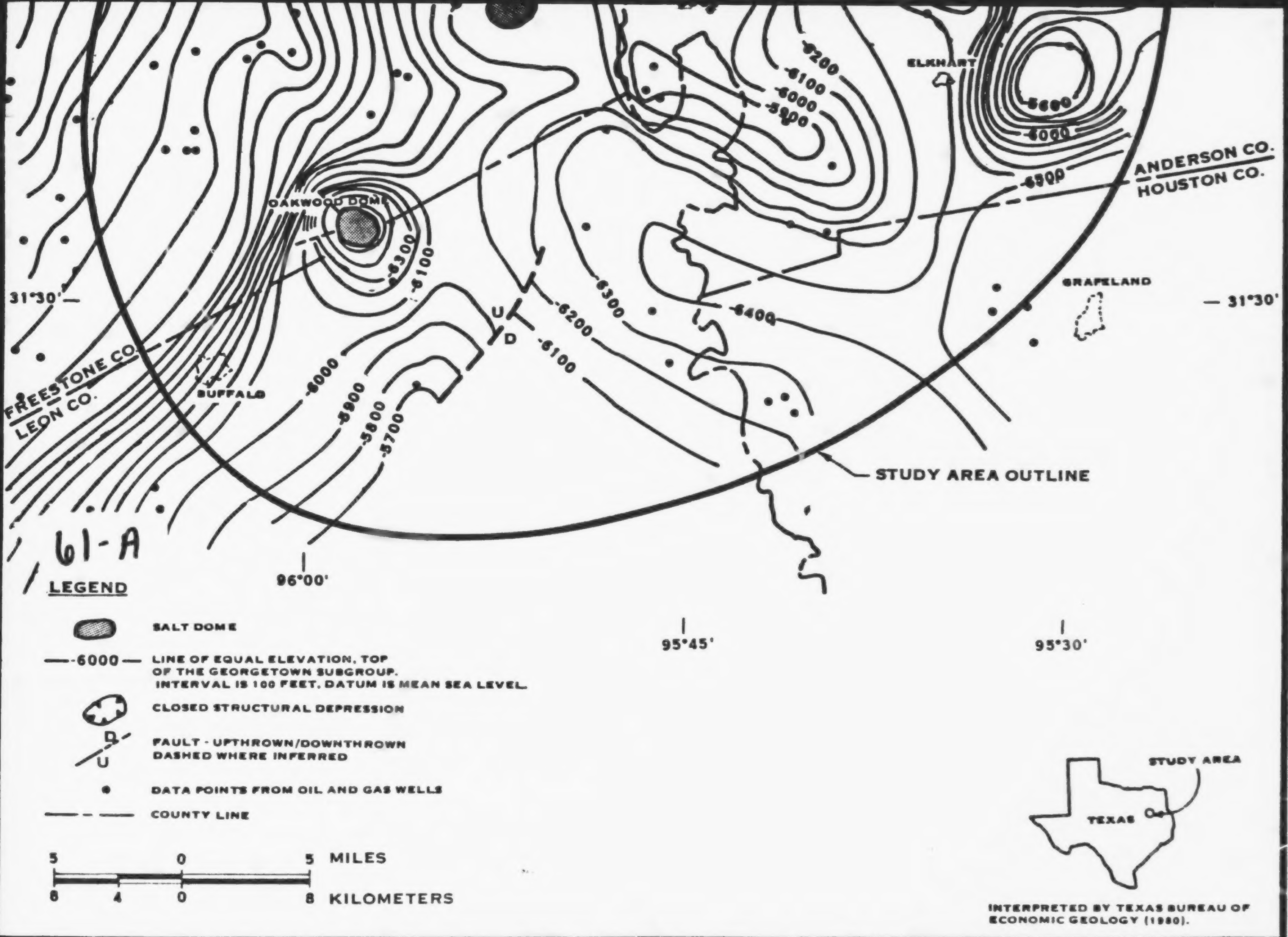

96°00'
95°45'
95°30'
N
32°00'
31°45'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
TRINITY RIVER
NECHES RIVER
FRANKSTON
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
-4300
-4400
-4500
-4600
-4700
-4800
-4900
-5000
-5100
-5200
-5300
-5400
-5500
-5600
-5700
-5800
-5900
-6000
-6100
-6200
-7000
-6500
-5900
-5600

61-A



-6200
-6100
-6000
-5900
ELKHART
-5600
-6000
-6500
ANDERSON CO.
HOUSTON CO.
OAKWOOD DOME
-6300
-6100
31°30'
-6300
-6400
U
D
-6200
-6100
GRAPELAND
31°30'
FREESTONE CO.
LEON CO.
BUFFALO
-6000
-5900
-5800
-5700
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
SALT DOME
-6000 LINE OF EQUAL ELEVATION, TOP OF THE GEORGETOWN SUBGROUP. INTERVAL IS 100 FEET, DATUM IS MEAN SEA LEVEL.
CLOSED STRUCTURAL DEPRESSION
D U FAULT - UPTHROWN/DOWNTHROWN DASHED WHERE INFERRED
DATA POINTS FROM OIL AND GAS WELLS
COUNTY LINE
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS
INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980).

PREPARED ______ DATE 5/15/80
REVISED GHF DATE 11/9/81
REVISED ______ DATE ______
APPROVED ______ DATE 8/15/80

T-1083-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
STRUCTURE - TOP OF GEORGETOWN SUBGROUP

JOB NO. MV9600

FIGURE 6-28

62

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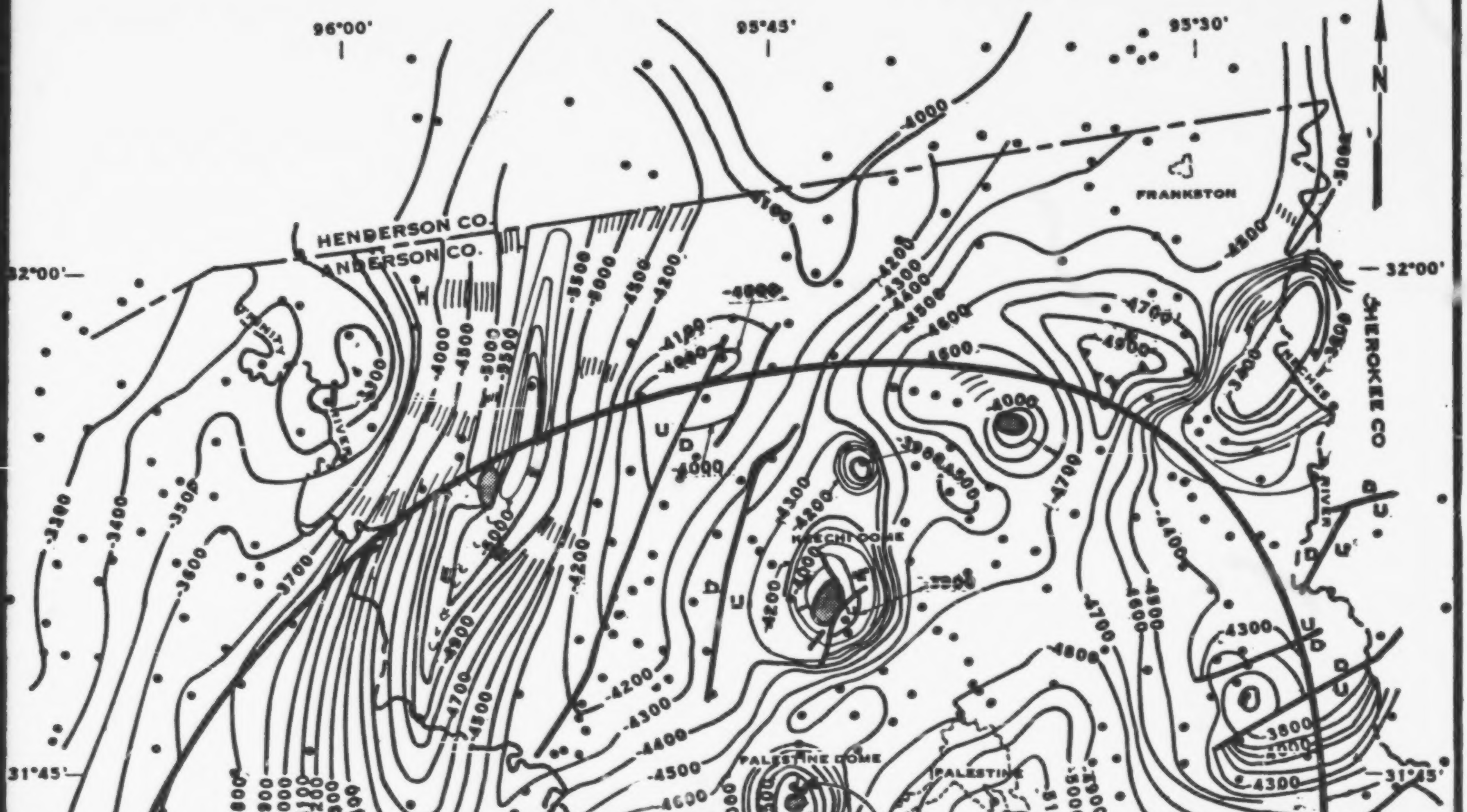
96°00'
95°45'
95°30'
N
32°00'
31°45'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
AUSTIN CHALK OUTCROP
ELKHART
RSON CO.
U
D
-3300
-3400
-3500
-3600
-3700
-3800
-3900
-4000
-4100
-4200
-4300
-4400
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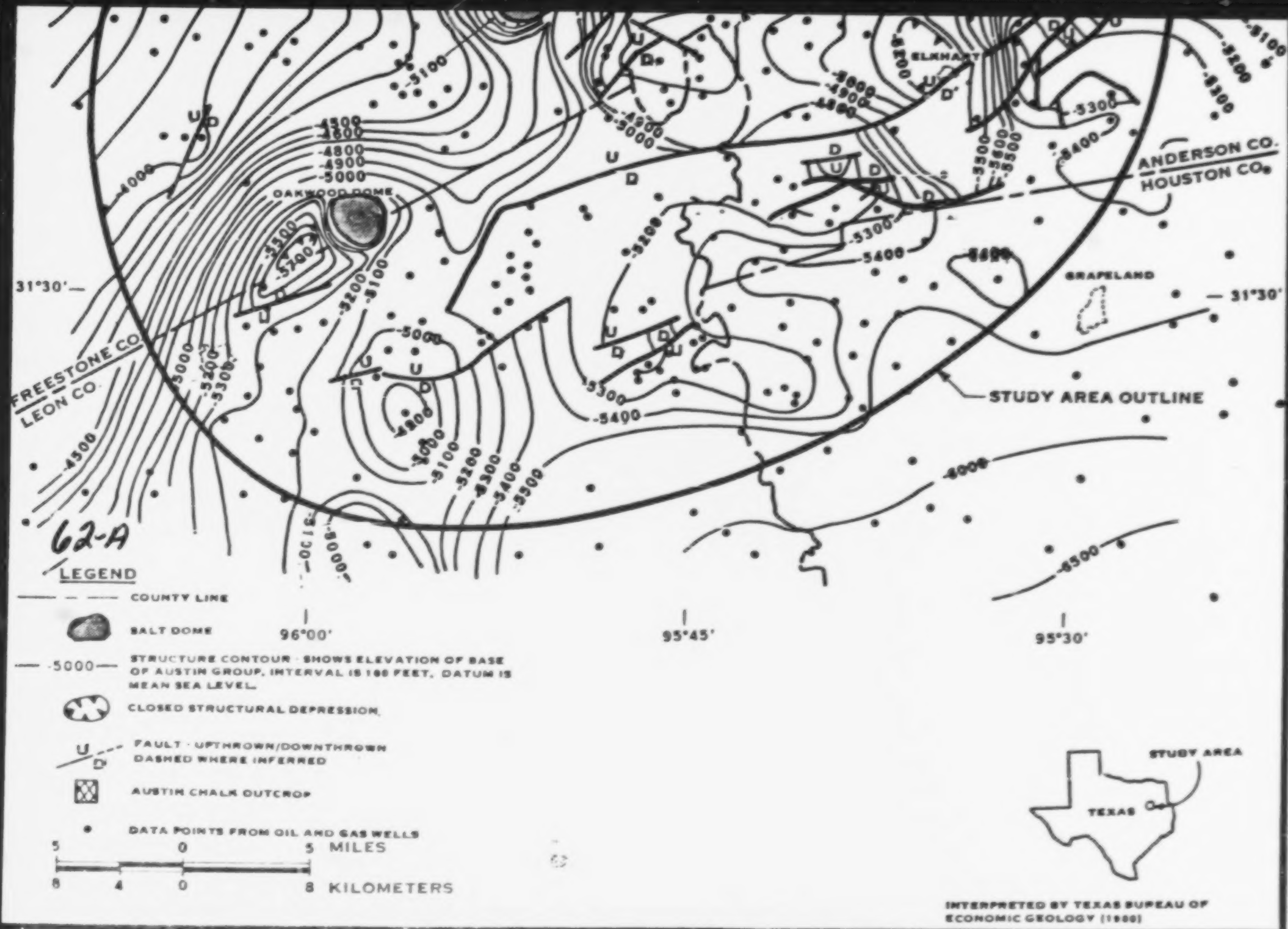
-5000
-5100
-5200
-5300


62-A
OAKWOOD DOME
ELKHART
GRAPELAND
ANDERSON CO.
HOUSTON CO.
FREESTONE CO.
LEON CO.
STUDY AREA OUTLINE
31°30'
96°00'
95°45'
95°30'
-4500
-4600
-4800
-4900
-5000
-5100
-5200
-5300
-5400
-5500
-5700
-6000
-6500
U
D
LEGEND
COUNTY LINE
SALT DOME
-5000 STRUCTURE CONTOUR - SHOWS ELEVATION OF BASE OF AUSTIN GROUP, INTERVAL IS 100 FEET, DATUM IS MEAN SEA LEVEL.
CLOSED STRUCTURAL DEPRESSION
U/D FAULT - UPTHROWN/DOWNTHROWN DASHED WHERE INFERRED
AUSTIN CHALK OUTCROP
DATA POINTS FROM OIL AND GAS WELLS
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS
INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

PREPARED	[illegible]	DATE	[illegible]
REVISED	GHF	DATE	11/9/81
REVISED		DATE	
APPROVED	[illegible]	DATE	[illegible]

T-1084-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

STRUCTURE - BASE OF
AUSTIN GROUP

JOB NO. MV9600

FIGURE 6-29

63

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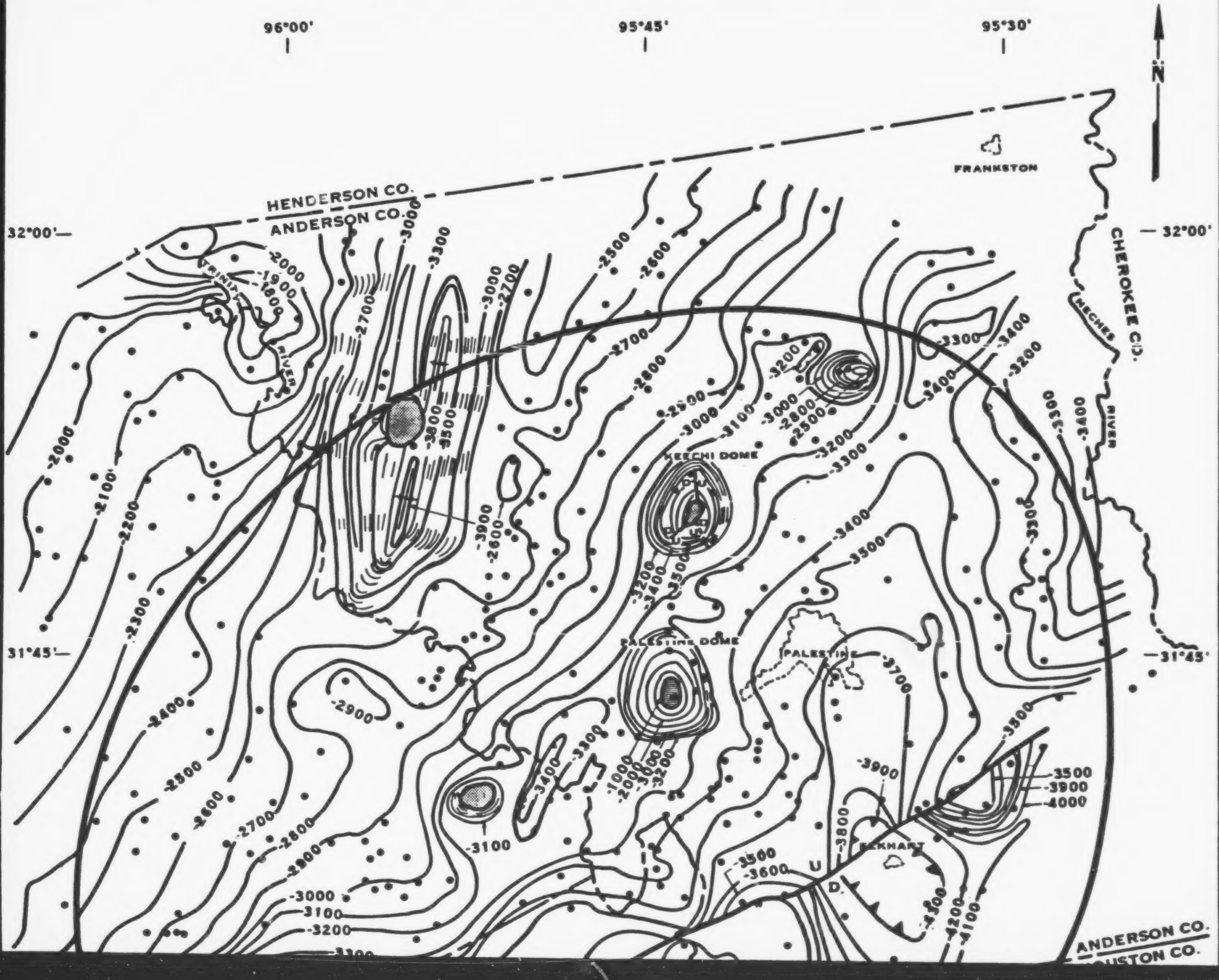
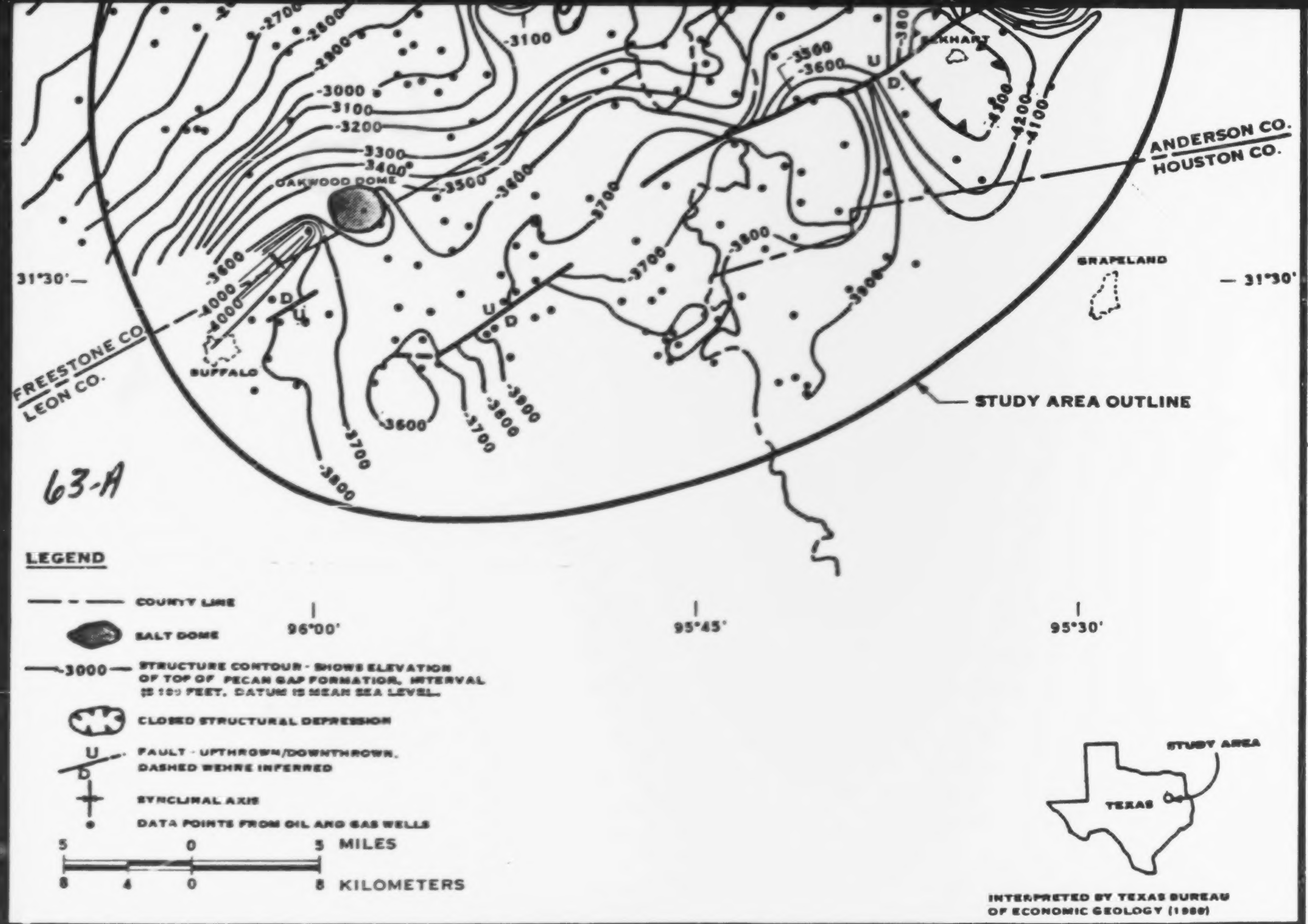

96°00'
95°45'
95°30'
N
32°00'
31°45'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
U
D
-1800
-1900
-2000
-2100
-2200
-2300
-2400
-2500
-2600
-2700
-2800
-2900
-3000
-3100
-3200
-3300
-3400
-3500
-3600
-3700
-3800
-3900
-4000
-4100
-4200
-1000
ANDERSON CO.
HOUSTON CO.


-2700
-2800
-2900
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-3100
-3200
-3300
-3400
-3500
-3600
-3700
-3800
-3900
-4000
-4100
-4200
-4300
ELKHART
OAKWOOD DOME
U
D
ANDERSON CO.
HOUSTON CO.
GRAPELAND
31°30'
BUFFALO
FREESTONE CO.
LEON CO.
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
COUNTY LINE
SALT DOME
-3000
STRUCTURE CONTOUR - SHOWS ELEVATION OF TOP OF PECAN GAP FORMATION, INTERVAL IS 100 FEET. DATUM IS MEAN SEA LEVEL.
CLOSED STRUCTURAL DEPRESSION
FAULT - UPTHROWN/DOWNTHROWN, DASHED WEHRE INFERRED
SYNCLINAL AXIS
DATA POINTS FROM OIL AND GAS WELLS
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS
INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

63-A

PREPARED		DATE	8/5/80
REVISED	GHF	DATE	11/9/81
REVISED		DATE	
APPROVED		DATE	8/15/80

T-1085-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
STRUCTURE - TOP OF
PECAN GAP FORMATION

JOB NO. MV9600

FIGURE 6-30

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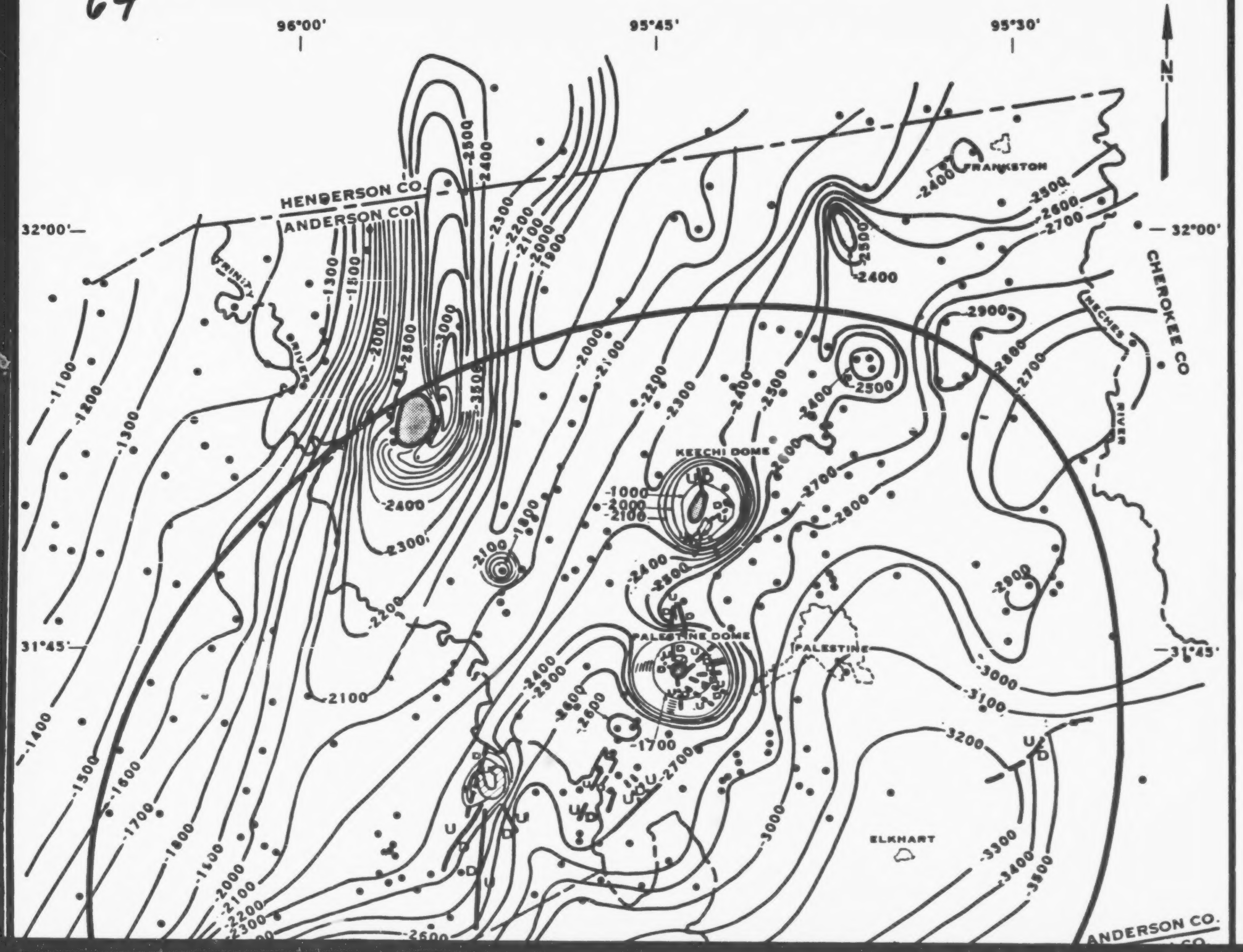
96°00'
95°45'
95°30'
N
HENDERSON CO.
ANDERSON CO.
32°00'
32°00'
TRINITY RIVER
FRANKSTON
CHEROKEE CO
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
31°45'
31°45'
ANDERSON CO.
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
-2100
-2200
-2300
-2400
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-3500
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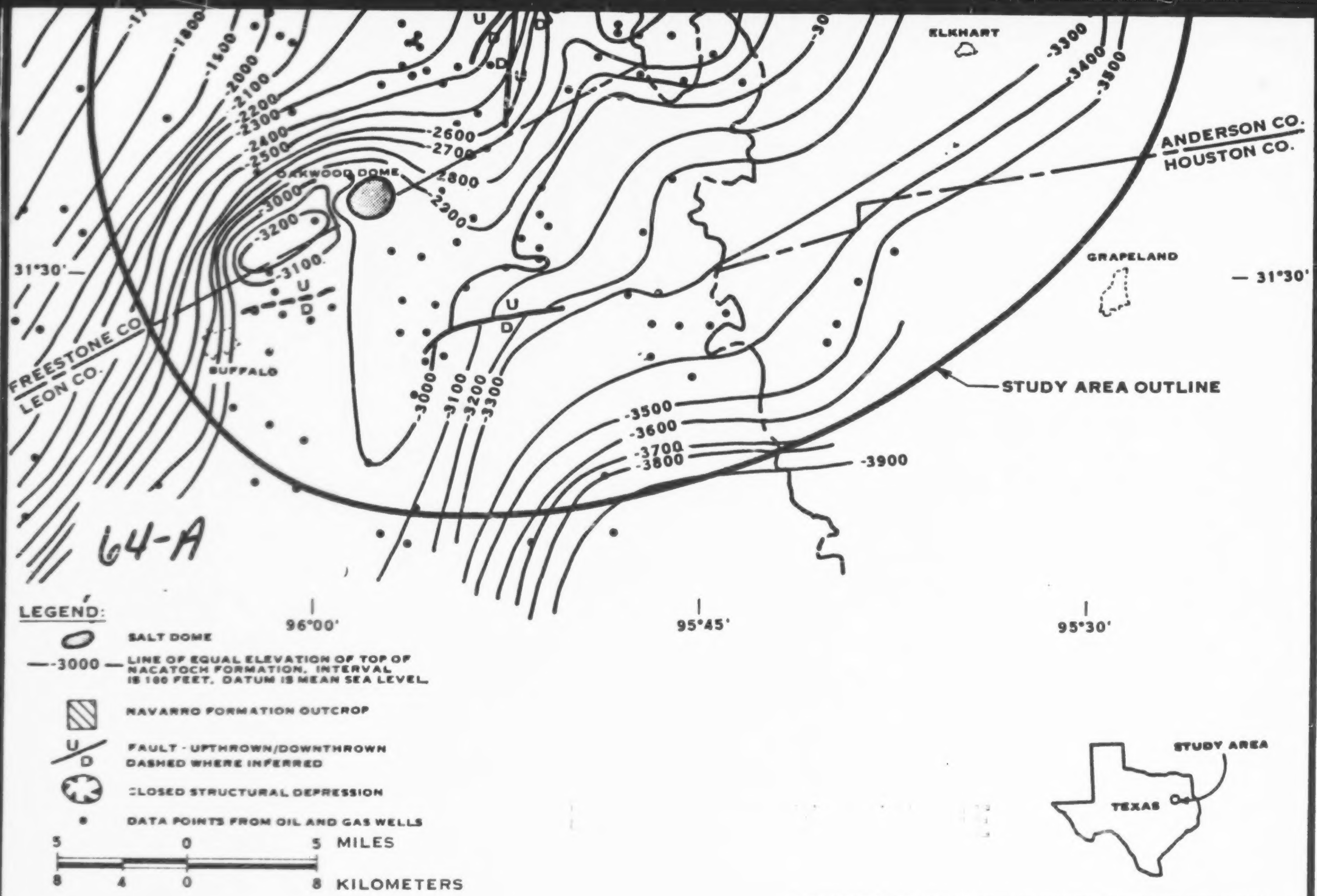
ELKHART
-3300
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-2200
-2300
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-2600
-2700
2800
-2200
OAKWOOD DOME
-3000
-3200
-3100
U
D
ANDERSON CO.
HOUSTON CO.
GRAPELAND
31°30'
— 31°30'
FREESTONE CO.
LEON CO.
BUFFALO
-3000
-3100
-3200
-3300
-3500
-3600
-3700
-3800
-3900
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND:
SALT DOME
—-3000— LINE OF EQUAL ELEVATION OF TOP OF NACATOCH FORMATION. INTERVAL IS 100 FEET. DATUM IS MEAN SEA LEVEL.
NAVARRO FORMATION OUTCROP
FAULT - UPTHROWN/DOWNTHROWN DASHED WHERE INFERRED
CLOSED STRUCTURAL DEPRESSION
DATA POINTS FROM OIL AND GAS WELLS
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS

64-A

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980).

PREPARED [illegible] DATE 2/15/80
REVISED GHF DATE 11/9/81
REVISED ______ DATE ______
APPROVED JMF DATE [illegible]

T-1086-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

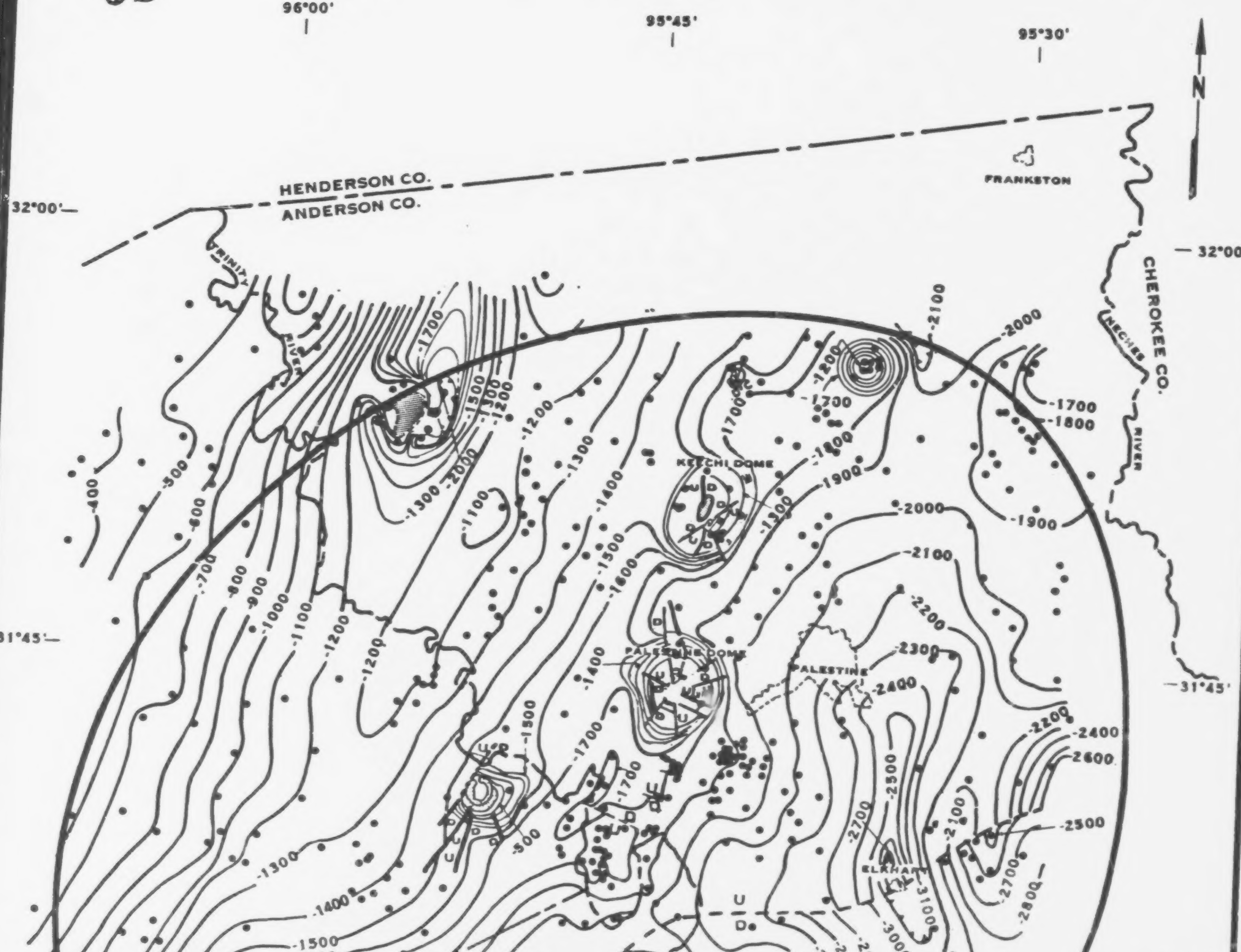
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
STRUCTURE - TOP OF NACATOCH FORMATION

JOB NO. MV9600

FIGURE 6-31

65


96°00'
95°45'
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N
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32°00'
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31°45'
HENDERSON CO.
ANDERSON CO.
FRANKSTON
CHEROKEE CO.
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
ANDERSON CO.
HOUSTON CO.
U
D
-400
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-2800
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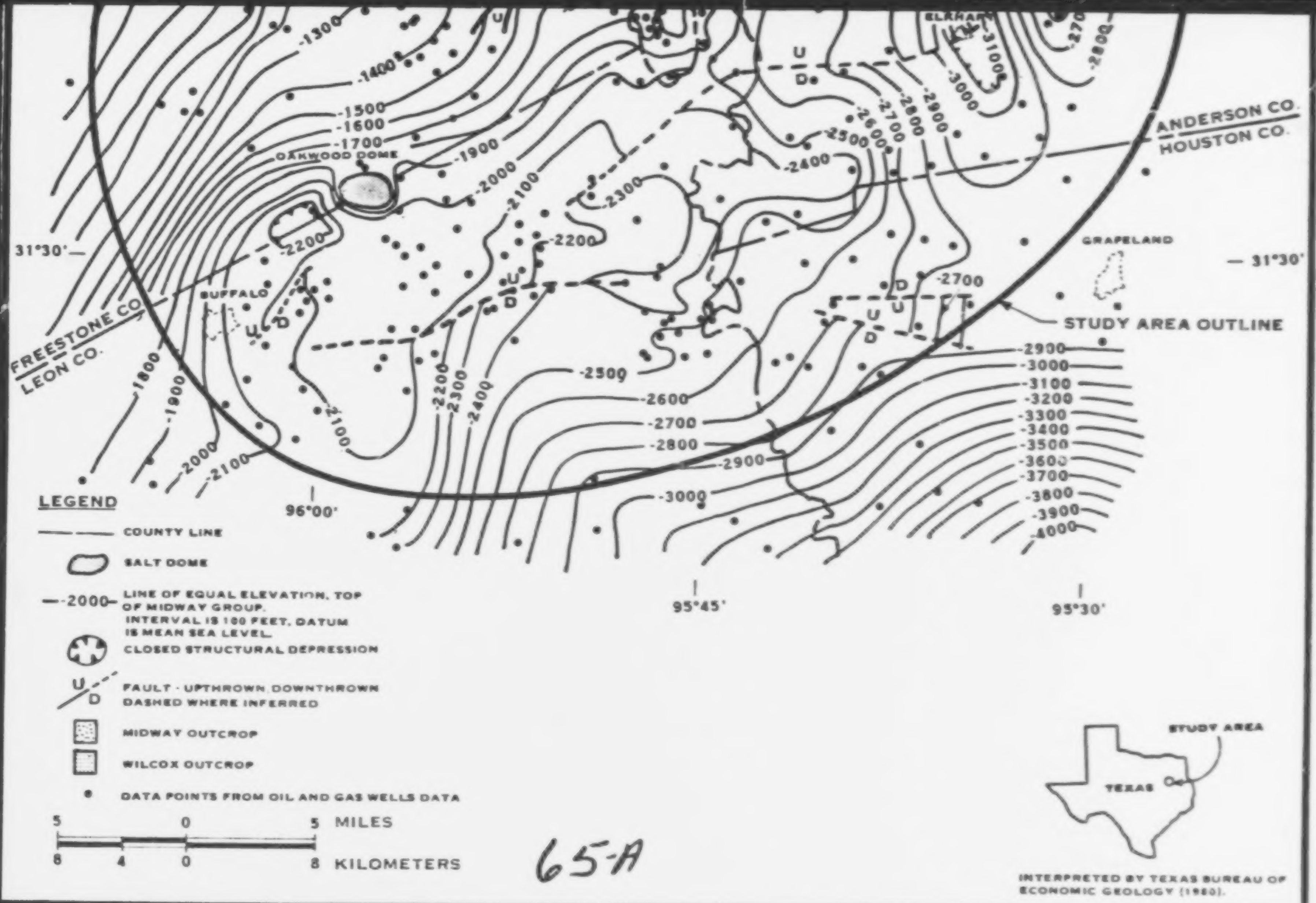
-3000
-3100


-1300
-1400
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-1900
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-2100
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-2400
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-2600
-2700
-2800
-2900
-3000
-3100
-3200
-3300
-3400
-3500
-3600
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-3800
-3900
-4000
1800
1900
2000
2100
OAKWOOD DOME
ELKHART
BUFFALO
GRAPELAND
ANDERSON CO.
HOUSTON CO.
FREESTONE CO.
LEON CO.
STUDY AREA OUTLINE
U
D
31°30'
96°00'
95°45'
95°30'
LEGEND
COUNTY LINE
SALT DOME
-2000 LINE OF EQUAL ELEVATION, TOP OF MIDWAY GROUP. INTERVAL IS 100 FEET, DATUM IS MEAN SEA LEVEL.
CLOSED STRUCTURAL DEPRESSION
FAULT - UPTHROWN, DOWNTHROWN DASHED WHERE INFERRED
MIDWAY OUTCROP
WILCOX OUTCROP
DATA POINTS FROM OIL AND GAS WELLS DATA
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS
INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980).

65-A

PREPARED ______ DATE ______
REVISED GHF DATE 11/9/81
REVISED ______ DATE ______
APPROVED ______ DATE ______

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

STRUCTURE - TOP OF MIDWAY

JOB NO. MV9600

FIGURE 6-32

6.2.5.1 Historic Seismicity: The East Texas Salt Basin is located in a region of low seismic activity. Figure 6-33 illustrates the locations and intensities of the historic earthquakes which occurred within the study area and surrounding region. East Texas Study Area Appendix Table G-1.1 elaborates on the details of each earthquake.

6.2.5.2 Regional Tectonics and Seismicity: As stated before, subsidence in the Northeast Texas Embayment ceased by early Tertiary Eocene time.

No geologic record exists within the study area to cover the time elapsed between the middle Eocene and early Pleistocene.

Based on National Geodetic Survey (NGS) data (Holdahl and Morrison, 1974), BEG (Collins and others, 1980) postulated a modern elevation rise of 3 to 5 mm/yr (0.12 to 0.19 in/yr) in East Texas during a period of 33 years from 1940 to 1973. The leveling profile has a northwest-southeast orientation and crosses over the Mt. Enterprise Fault Zone at approximately 32 km (20 mi) outside and to the east of the study area (Figure 6-34).

A review of the state of the art in first-order leveling determined that premature conclusions may have been drawn when comparing data collected at different times without systematic analysis of the changes in data collection techniques, instrumentation, calibration procedures, and data reduction methods which occurred in the interim between successive investigations. That is to say, the NGS data may not be correct and the elevation may not have changed.

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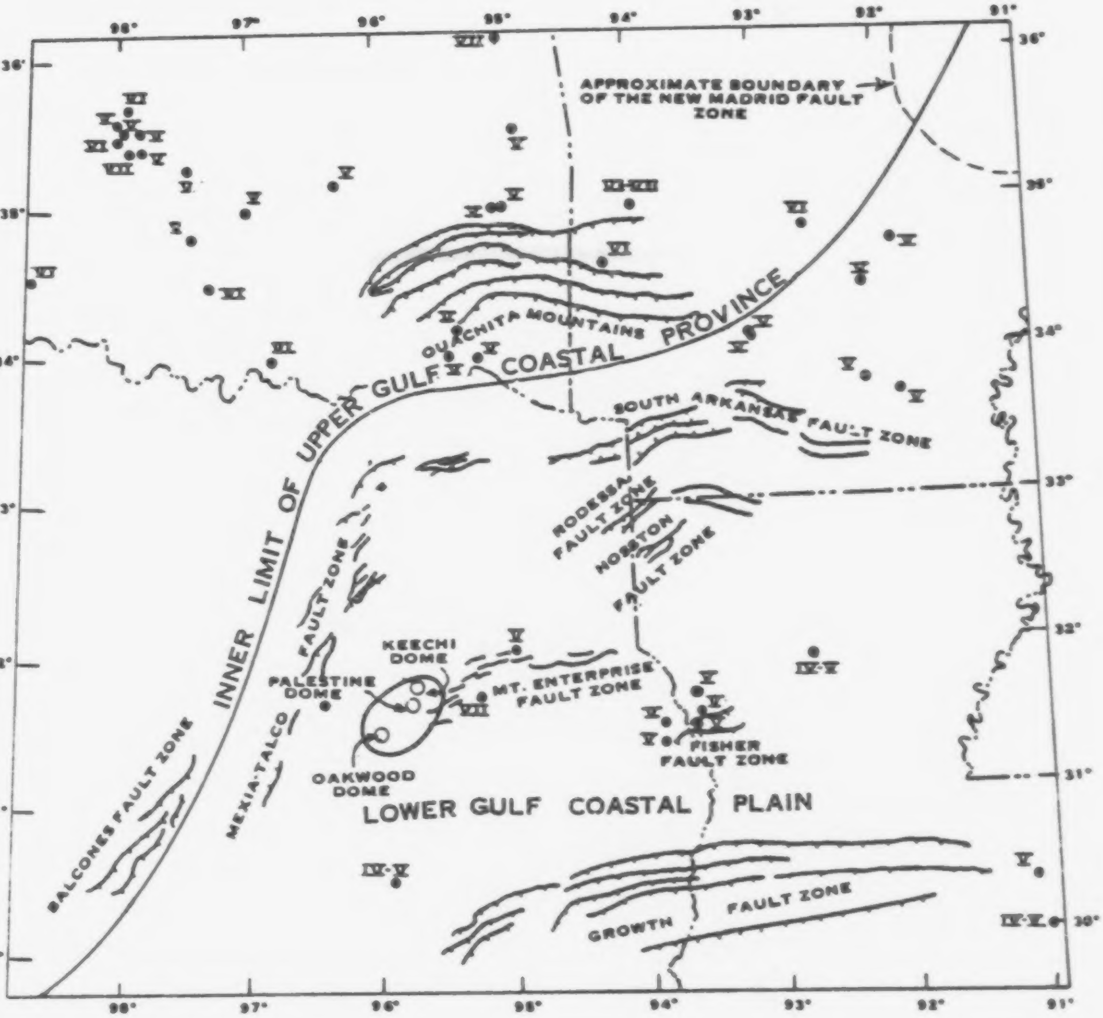
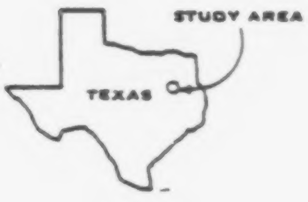

APPROXIMATE BOUNDARY OF THE NEW MADRID FAULT ZONE
OUACHITA MOUNTAINS
INNER LIMIT OF UPPER GULF COASTAL PROVINCE
SOUTH ARKANSAS FAULT ZONE
RODESSA FAULT ZONE
HOSSTON FAULT ZONE
MEXIA-TALCO FAULT ZONE
BALCONES FAULT ZONE
KEECHI DOME
PALESTINE DOME
OAKWOOD DOME
MT. ENTERPRISE FAULT ZONE
FISHER FAULT ZONE
LOWER GULF COASTAL PLAIN
GROWTH FAULT ZONE
N
98° 97° 96° 95° 94° 93° 92° 91°
36° 35° 34° 33° 32° 31° 30°

LEGEND

● EARTHQUAKE EPICENTERS, INTENSITY (MM) IV-V OR GREATER

NORMAL FAULT, HACHURED ON DOWNTHROWN SIDE


STUDY AREA
TEXAS

60 0 60 MI

96 0 96 KM

EPICENTERS WITHIN THE NEW MADRID FAULT ZONE HAVE NOT BEEN PLOTTED DUE TO HIGH DENSITY SPACING AND SCALE LIMITATIONS.

SEE TABLE G-1.1 FOR LIST OF EVENTS.

PREPARED [illegible] DATE [illegible] REVISED GHF DATE 11/9/81 REVISED ____ DATE ____ APPROVED [illegible] DATE [illegible] T-1096-1	NATIONAL WASTE TERMINAL STORAGE PROGRAM GEOLOGIC EVALUATION GULF COAST SALT DOMES LAW ENGINEERING TESTING COMPANY MARIETTA GEORGIA	EAST TEXAS STUDY AREA REGIONAL EPICENTER LOCATION MAP JOB NO. MV9600 FIGURE 6-33

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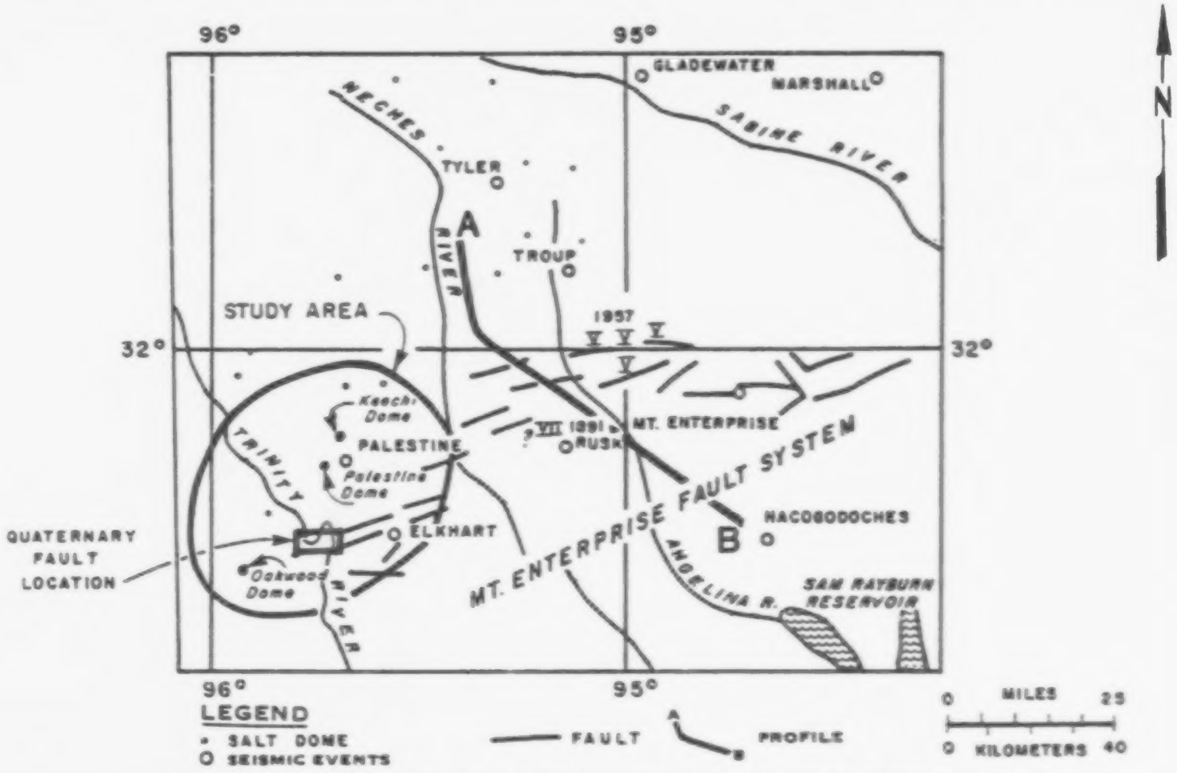
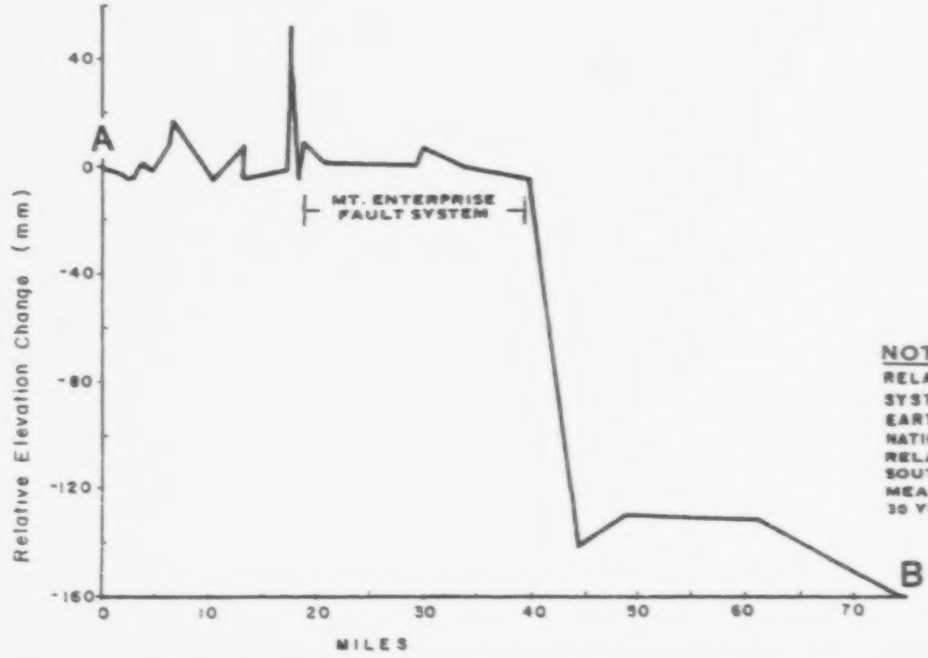
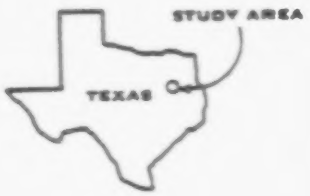

N
96°
95°
32°
GLADEWATER
MARSHALL
SABINE RIVER
NECHES
TYLER
RIVER
A
TROUP
STUDY AREA
1957
V V V
V
Keechi Dome
PALESTINE
Palestine Dome
VII 1891
RUSK
MT. ENTERPRISE
MT. ENTERPRISE FAULT SYSTEM
NACOGDOCHES
B
TRINITY
RIVER
ELKHART
QUATERNARY FAULT LOCATION
Oakwood Dome
ANGELINA R.
SAM RAYBURN RESERVOIR
LEGEND
SALT DOME
SEISMIC EVENTS
FAULT
A B PROFILE
0 MILES 25
0 KILOMETERS 40

MM V 1957 EPICENTER OF FOUR EARTHQUAKES THAT OCCURRED ON MARCH 19, 1957

MM VII 1891 EPICENTER OF "QUESTIONABLE" RUSK EARTHQUAKE THAT OCCURED ON JANUARY 8, 1891




STUDY AREA
TEXAS

NOTE

RELATION OF MT. ENTERPRISE FAULT SYSTEM TO PREVIOUS REPORTS OF EARTHQUAKES AND THE LINE LEVELED BY NATIONAL GEODETIC SURVEY. RELATIVE ELEVATION CHANGES AT SOUTHERN EDGE OF FAULT SYSTEM MEASURED OVER APPROXIMATELY 30 YEAR PERIOD.

REFERENCE

COLLINS AND OTHERS, 1980

PREPARED TH DATE 8/81
REVISED GHF DATE 11/9/81
REVISED ____ DATE ____
APPROVED ____ DATE ____
T-1097-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
LOCATION AND COMPARISON OF NGS LEVELS NEAR THE STUDY AREA
JOB NO. MV9600 FIGURE 6-34

It has been postulated that the Mt. Enterprise Fault Zone acted as a hinge line between the Gulf Coast Basin and the East Texas Basin (Kreitler and others, 1980). A link could exist between active tectonism along the Mt. Enterprise Fault Zone and the relative velocity of ground-level change, inferrable from the NGS data if the data prove to be correct.

Minor faulting at the surface within the study area, affecting Quaternary deposits along the Trinity River, has been reported (Collins and others, 1980) (Figures 6-23 and 6-24). This Quaternary faulting, which was described in Subsection 6.2.3, occurs along the surface projection of the subsurface western extension of the Mt. Enterprise Fault Zone.

According to Collins and others (1980) the fault on the Trinity River within the study area "establishes positive evidence of Quaternary tectonism in East Texas". The fault strikes in the general trend of the Mt. Enterprise Fault Zone (Figure 6-34) and has been correlated with another major fault of the fault zone. The Trinity River Fault lies west of the westernmost known surface expression of major faulting in the system. The magnitude of displacement of the fault in Eocene beds (directly overlain by the minor displacements in Quaternary beds described) is significantly less than that for faulting associated with the Mt. Enterprise Fault Zone farther east, where it has been mapped east of the Trinity River. This might suggest that the Mt. Enterprise Fault Zone progressively diminishes westward before dying out within the study area. Subsurface evidence corroborates this conclusion (Figures 6-11, 6-18, 6-20, 6-21 and 6-22).

The Trinity River Fault is reported to be on the southern edge of the Long Lake Oil Field, where several faults mapped in the subsurface Cretaceous strata strike in the same direction. However, BEG does not believe the "active" Trinity River surface fault to be related to faulting at Long Lake Field because it has not been demonstrated that the subsurface faulting extends to the surface.

Field investigations of the Trinity River Fault yielded the following information:

(1) The condition of the exposure at the surface is poor

(2) Displacements in the underlying Eocene Claiborne beds do not extend into the overlying Quaternary units

(3) No vertical fractures are associated with the step-faults reported in the Eocene Claiborne beds

(4) The fractures or microshear zones reported in the Quaternary are nearly parallel to the bedding and do not extend down into the underlying Eocene Claiborne beds.

No evidence of displacement of Quaternary deposits has been found elsewhere in the vicinity of the Mt. Enterprise Fault Zone.

A review of earthquake history determined that several earthquakes have been recorded in the region to the east of the study area. In 1891 an event was recorded near the town of Rusk (Figure 6-34) as an earthquake of intensity VII MM. The event has been questioned by Von Hake (1977), who believes the localized damages may have been caused by a severe storm. On March 19, 1957, four shocks of intensity V MM occurred over an area of about 25,900 km^2 (10,000 mi^2), with epicenters tentatively located around the coordinates 32° north latitude and 95° west longitude (Figure 6-34). Lack of sufficient seismic instrumentation at the time the events occurred made it impossible to pinpoint the epicenters with accuracy. Hence, correlation of these seismic events with movement on the Mt. Enterprise Fault Zone cannot be based on existing data.

A microseismic monitoring unit was installed in January 1980 at the location of a major fault in the system east of the Trinity River in Rusk County, 10.4 km (6.5 mi) north of Cushing, Texas to investigate the seismicity of the Mt. Enterprise Fault System. The unit has been periodically checked and the records evaluated (see Appendix).

Seismograms recorded during the period February 3 through June 23, 1980 have been analyzed. During this period there have been 3,055 hours of normal operation, with 2,587 hours during which background noise attributable to weather and cultural sources was at levels sufficiently low that low-amplitude seismic events could be identified with a high degree of confidence. No definite microearthquake activity has been detected to date.

6.2.5.3 Correlation of Epicenters: A study has been made to attempt correlation of earthquake epicenters with specific faults, fault zones, other geologic structures, storms, reservoirs, explosions, and oil and gas fields.

The injection and withdrawal of fluids in the subsurface have been demonstrated to induce earthquakes under certain conditions (Lee, 1978). The production of oil and gas involves the extraction of fluids (oil, gas, water) and the injection of fluids to enhance recovery fields with declining production. Both injection and extraction, and especially both operations in succession, can cause earthquakes to be felt locally, though such reports are not common.

Oil and gas production began in the Northeast Texas Embayment in the early 1900's. Earthquakes felt locally during the post-1900 period were selected from East Texas Study Area Appendix Table G-1.1 to examine the possibility that seismicity was related to oil and gas production. The Mexia-Wortham event of April 9, 1932, was labelled "suspect". According to the U.S. Earthquake, 1932, this earthquake generated intensity V MM ground motion. "Loose bricks were thrown down, plaster cracked, damage slight." It was also felt at Cooledge, Currie, Groesbeck, Hillsboro, League, and Richland. E. H. Sellards (1932) published an article in the University of Texas Bulletin No. 3201 about this earthquake, stating his belief that the probable cause of the earthquake was the extraction of oil and water from nearby oil fields. The epicenter was mapped 1.6 km (1 mi) east of the Mexia-Talco Fault Zone. The epicenter was located over the Mexia Field and 5 km (3 mi) south of the Wortham Field, both of which were discovered in 1920. The epicenter was also 8 km (5 mi) northeast of the Negro Creek Field and 11 km (7 mi) northeast of Groesbeck Field, which began production in 1926 and 1913, respectively. The substantial total production of oil, gas, and water from these fields through the year 1921 was estimated at 6,756,500,000 barrels (Sellards, 1932). In any highly productive oil and gas areas located on faults, similar relationships between fluid removal and injection with localized, minor earthquakes might occur.

The correlation of an event with a storm took place in Rusk, Texas and is described in Volume I, Chapter 2.0. No positive correlations have been established with geologic structures.

6.2.5.4 Seismic Risk Analysis: Only two possible correlations were made between documented historic earthquakes and geologic structures. This is an inadequate basis for risk analysis. Accordingly, analysis based on seismotectonic regions was used to establish seismic risk. Seismotectonic regions are areas of similar geologic and seismic activity. (For an overview of Interior Salt Basin Seismicity see Volume I, Section 2.5.) Figure 6-33 shows the location of the East Texas Salt Basin in the Interior Salt Basin Seismotectonic Region, which has an established maximum earthquake of intensity VI MM. This event, which occurred at Rusk, Texas in 1891, could theoretically have been generated anywhere within the regions or attenuated from the neighboring Wichita-Arbuckle or Ouachita Seismotectonic Regions to the north. However, none of the other neighboring provinces could have contributed an attenuated ground motion equal to an intensity VI MM earthquake during the period in question.

A return period and probability-of-exceedence calculation was made for the candidate domes in the East Texas Salt Basin. Figure 6-35 describes the results of this analysis. (Reference is made to Volume I, Chapter 2.0 for a description of this analysis technique.)

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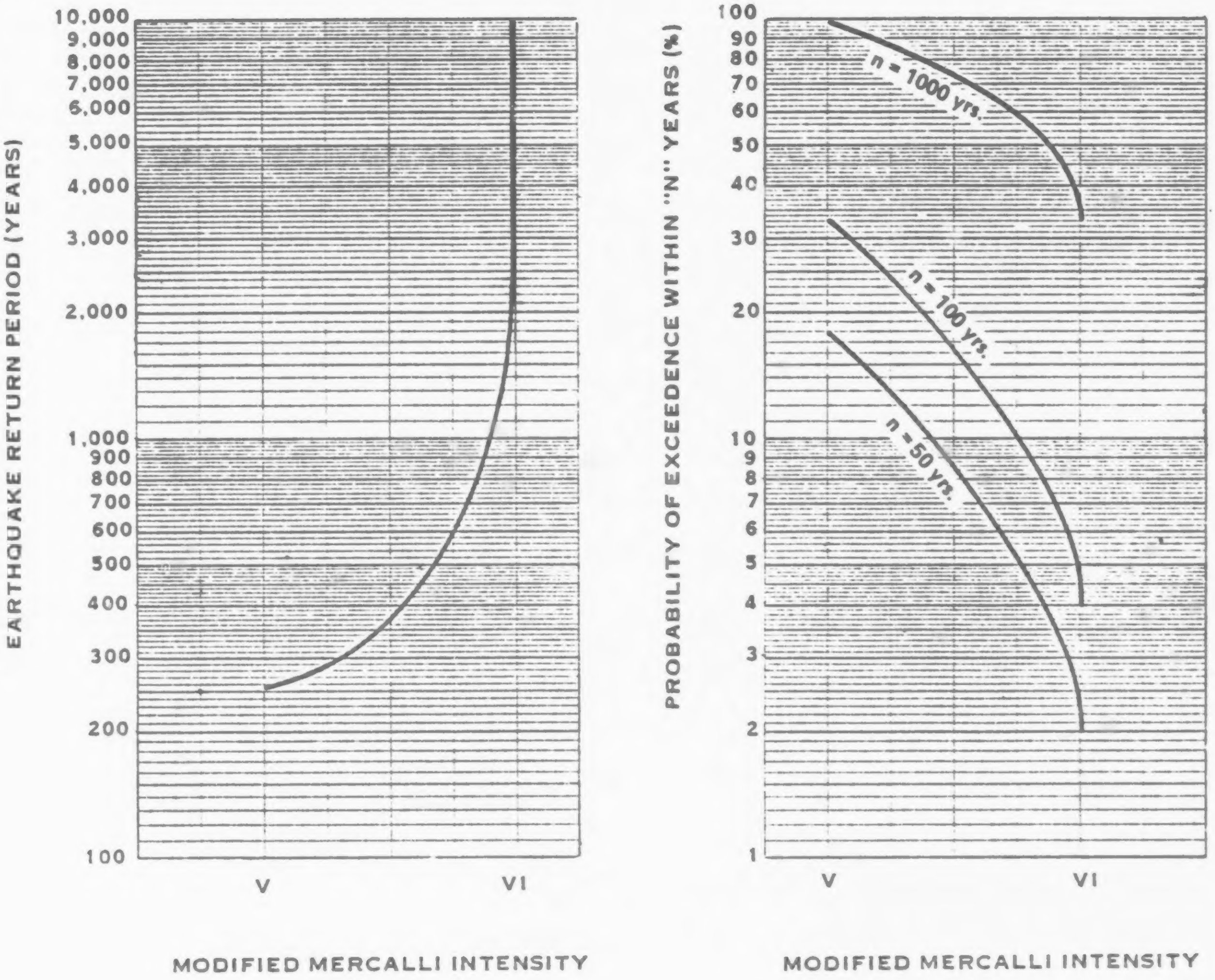

PREPARED ____ DATE ____ REVISED ____ DATE ____ REVISED ____ DATE ____ APPROVED ____ DATE ____ T-1018-1	NATIONAL WASTE TERMINAL STORAGE PROGRAM GEOLOGIC EVALUATION GULF COAST SALT DOMES LAW ENGINEERING TESTING COMPANY MARIETTA GEORGIA	EAST TEXAS STUDY AREA EARTHQUAKE RETURN PERIOD AND PROBABILITY OF EXCEEDENCE CURVES FROM THE STUDY AREA JOB NO. MV0600 FIGURE 6-35

In summary, seismic activity for the study area is historically low. The candidate salt domes in the East Texas Salt Basin Study Area can expect a maximum ground motion surface intensity of VI MM. No tectonic features were positively identified as capable of generating earthquakes.

6.3 MINERAL RESOURCES OF THE EAST TEXAS STUDY AREA

The mineral resources within the East Texas Study Area include: oil, gas, stone, salt, lignite, clay, peat, iron ore, rock aggregate, and sand and gravel. Significant or potentially significant mineral resource commodities within the study area were chosen for their past, present, or future (based on current trends) production capabilites. Petroleum is considered most significant of all the resources. Other significant resources within the study area are limited to salt, stone, and lignite.

6.3.1 HYDROCARBON RESOURCES: Within the study area, oil and gas production is from Upper Jurassic to Tertiary reservoirs to depths in excess of 3,658 meters (12,000 ft). Of 56 oil and gas fields (Figures 6-36 and 6-37), 35 reported production, 4 reported no production, and 19 were abandoned (Railroad Commission of Texas, 1979).

Production for the majority of the fields (94 percent) in the area is from Cretaceous sediments, including the Upper Cretaceous Pecan Gap Formation, the Sub-Clarksville member of the Eagle Ford Group, the Woodbine Group, the Lower Cretaceous Rodessa member of the Georgetown Formation, the Pettet Formation, and the Travis

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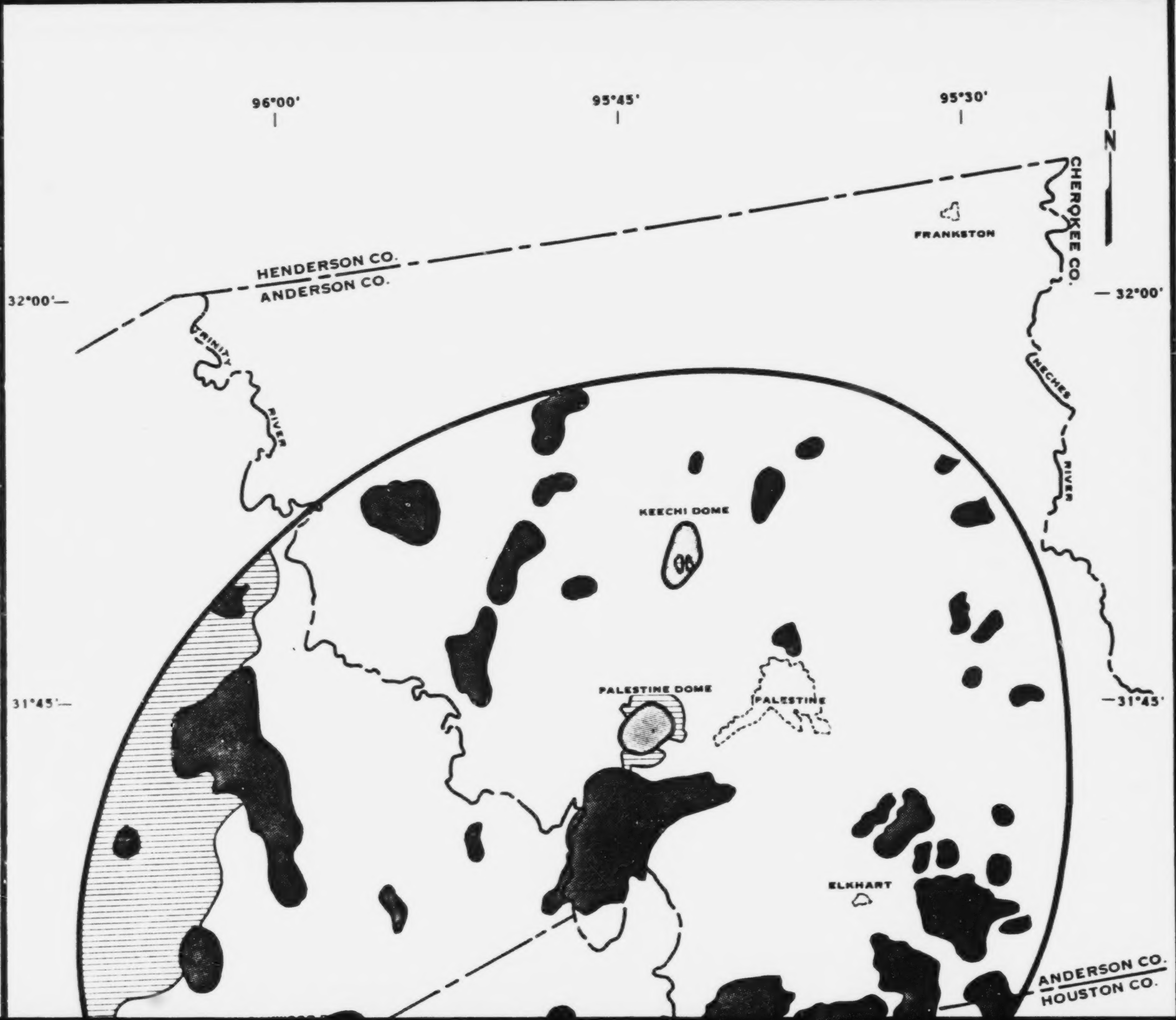
96°00'
95°45'
95°30'
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32°00'
32°00'
31°45'
31°45'
HENDERSON CO.
ANDERSON CO.
CHEROKEE CO.
FRANKSTON
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
ANDERSON CO.
HOUSTON CO.

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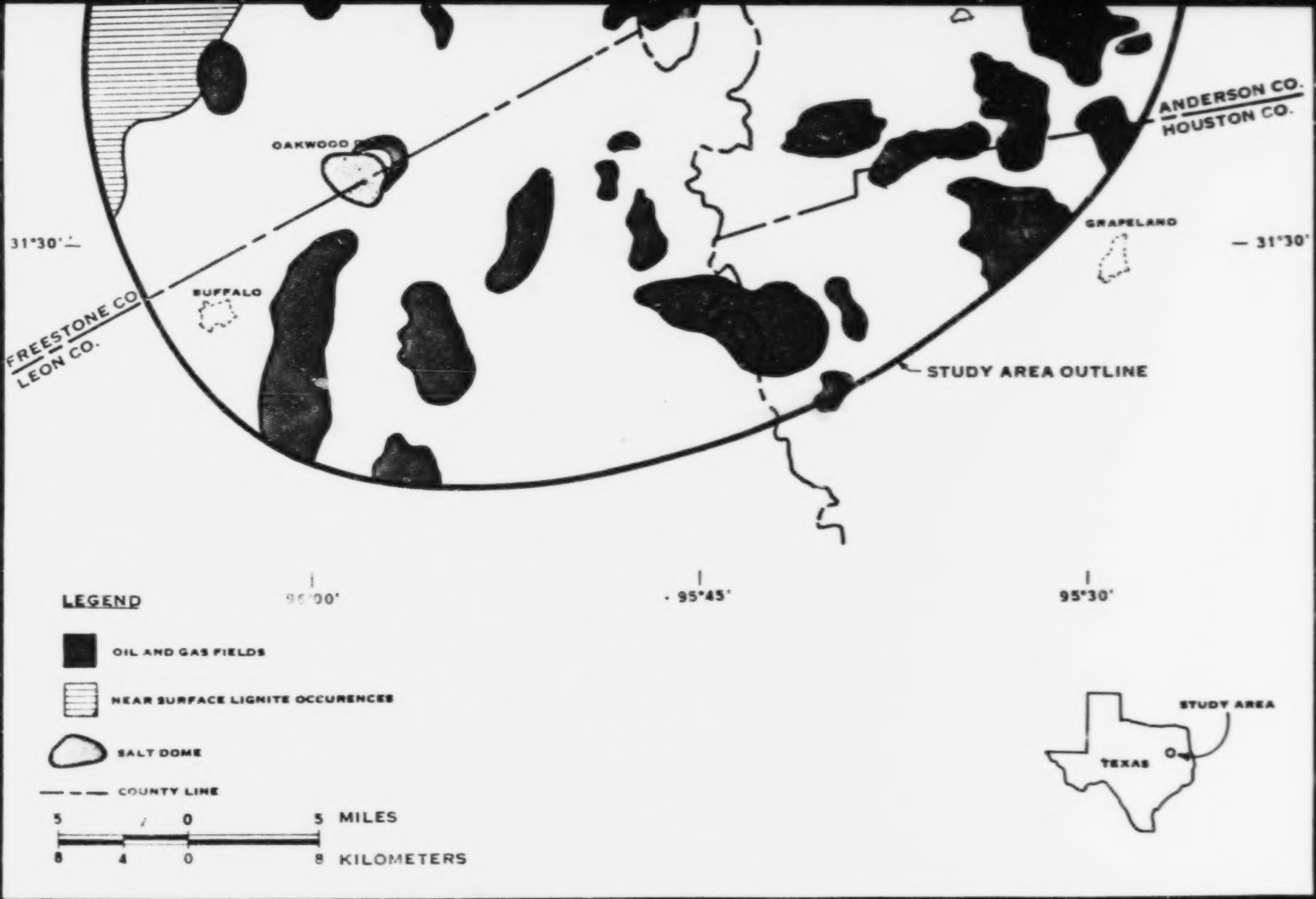
ANDERSON CO.
HOUSTON CO.
OAKWOOD
31°30'
— 31°30'
GRAPELAND
BUFFALO
FREESTONE CO.
LEON CO.
STUDY AREA OUTLINE
96°00'
95°45'
95°30'
LEGEND
OIL AND GAS FIELDS
NEAR SURFACE LIGNITE OCCURENCES
SALT DOME
COUNTY LINE
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS

PREPARED REVISED GHF REVISED APPROVED	DATE 2/1/80 DATE 11/9/81 DATE DATE 2/15/80	
NATIONAL WASTE TERMINAL STORAGE PROGRAM GEOLOGIC EVALUATION GULF COAST SALT DOMES LAW ENGINEERING TESTING COMPANY MARIETTA GEORGIA	EAST TEXAS STUDY AREA OIL AND GAS FIELDS AND LIGNITE OCCURENCES	

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FIGURE 6-36

FIGURE 6-36

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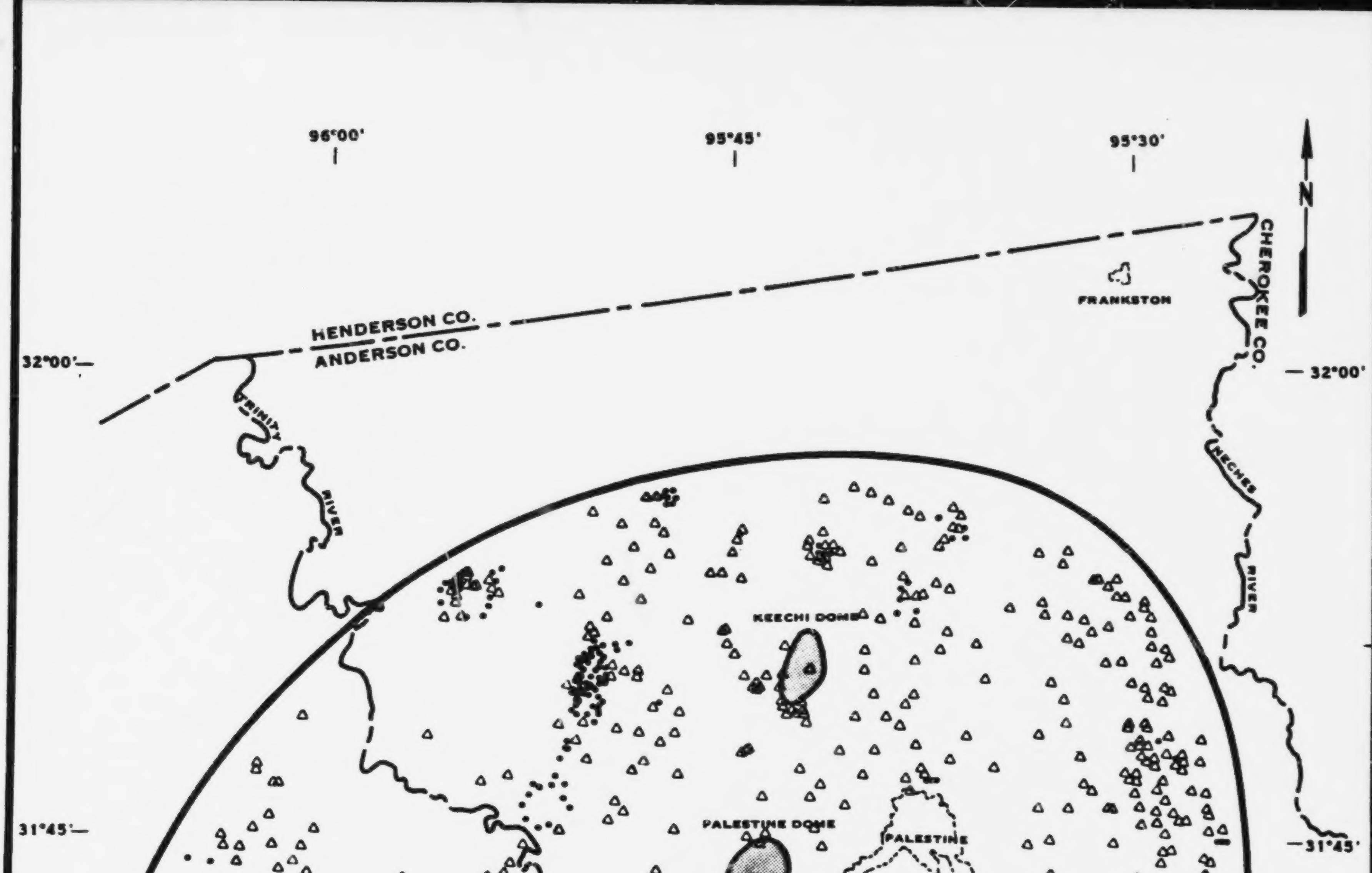
96°00'
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95°30'
N
CHEROKEE CO.
FRANKSTON
HENDERSON CO.
ANDERSON CO.
32°00'
32°00'
TRINITY RIVER
NECHES RIVER
KEECHI DOME
PALESTINE DOME
PALESTINE
ELKHART
31°45'
31°45'
NDERSON CO.

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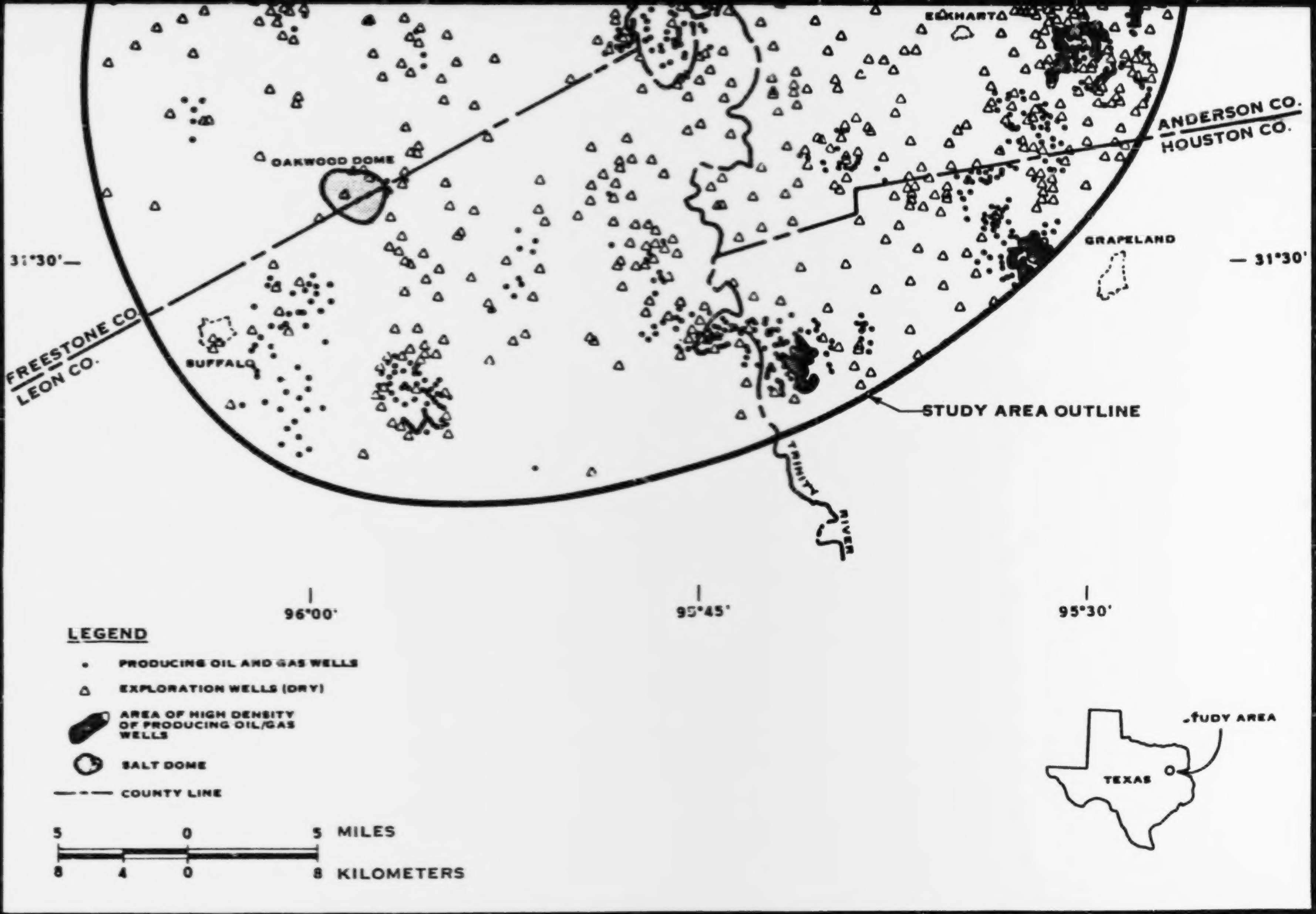
EKHART
ANDERSON CO.
HOUSTON CO.
OAKWOOD DOME
GRAPELAND
31°30'
31°30'
FREESTONE CO.
LEON CO.
BUFFALO
STUDY AREA OUTLINE
TRINITY RIVER
96°00'
95°45'
95°30'
LEGEND
PRODUCING OIL AND GAS WELLS
EXPLORATION WELLS (DRY)
AREA OF HIGH DENSITY OF PRODUCING OIL/GAS WELLS
SALT DOME
COUNTY LINE
5
0
5
MILES
8
4
0
8
KILOMETERS
STUDY AREA
TEXAS

PREPARED [illegible] DATE [illegible]
REVISED GUF DATE 11/9/81
REVISED DATE
APPROVED [illegible] DATE [illegible]

T-1099-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

LOCATION OF EXPLORATION AND PRODUCTION WELLS

JOB NO. MV9600

FIGURE 6-37

FIGURE 6-37

Peak Group. The remaining production is from the Upper Jurassic Cotton Valley Group, and from the Tertiary Wilcox Group and Carrizo Formation. Although the production of oil in the study area is declining, gas production is increasing. Table 6-2 summarizes the field data for oil and gas fields within the study area, including producing formations and 1978 annual and cumulative oil, casing-head gas, condensate, and gas production.

The trapping mechanisms within the area are of three types: structural, stratigraphic, and hydrodynamic, a combination of any two or three of these mechanisms also being probable. Of the three trapping mechanisms in the study area, structural traps are responsible by far for the major part of the production. Hydrocarbon traps that are structurally related include fault traps, convex flexure traps, piercement traps, and structural salients (Murray, 1957). These traps can be of regional or local extent, or both. Fields associated with the Mt. Enterprise Fault System can be considered to be the regional type, although some are not exclusively structural. Examples include the Elkhart Field and the numerous Slocum Fields. Structural traps within the study area, with the exception of those associated with the Mt. Enterprise Fault Zone, are of local extent, associated with structural domes and anticlines, salt domes, and faulting.

Hydrocarbon trapping mechanisms related to stratigraphic conditions include pinch-out or wedging of reservoir rocks, variations in permeability and porosity, and truncation of porous beds (Murray, 1957). Like structurally related traps, stratigraphic traps can be either regional or local types, but only those of

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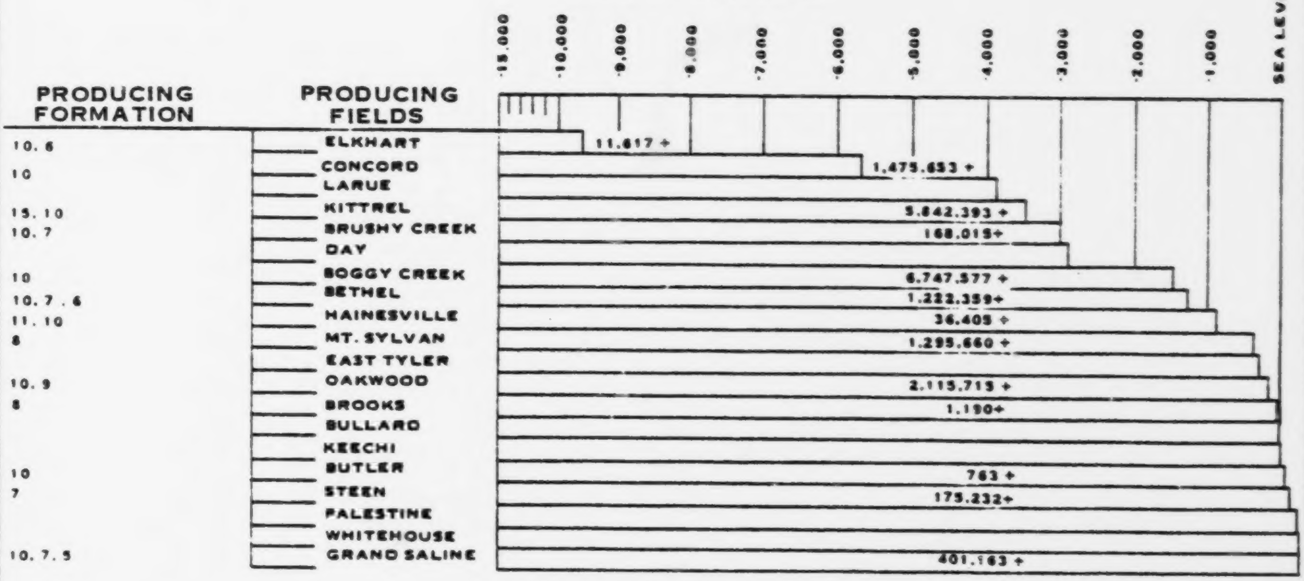
CHART SHOWING HIGHEST DRILLED SALT, CUMULATIVE PRODUCTION AND PRODUCING BEDS ON INTERIOR DOMES

EAST TEXAS



KEY TO PRODUCING FORMATION

1	NORPHLET	6	NUEVOLEON-DURANGO	11	EAGLEFORD
2	SMACKOVER	7	TRINITY	12	AUSTIN
3	BUCKNER	8	PALUXY	13	TAYLOR
4	HAYNESVILLE	9	WASHITA-FREDERICKSBURG	14	NAVARRO
5	COTTON VALLEY	10	WOODBINE-TUSCALOOSA	15	PALEOCENE-EOCENE

PREPARED ______ DATE ______
REVISED GHF DATE 11/9/81
REVISED ______ DATE ______
APPROVED ______ DATE ______
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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
STUDY AREA OIL AND GAS FIELD SUMMARY

JOB NO.
MV9600
TABLE NO. 6-2

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79

local extent are present in the study area. The Tennessee Colony Field, which produces from the Pettet Formation, is a prime example of a stratigraphic trap (although there is some structural closure) resulting largely from internal variations in porosity and permeability. Production in this field is from a porous reef facies of the Rodessa enclosed by more dense and impermeable limestone facies.

Although no example of a purely hydrodynamic trap is present in the study area, many of the structural and stratigraphic traps are enhanced by hydrodynamic forces acting on the reservoir rock. These typically are associated with the Upper Cretaceous and younger sediments, which are predominantly clastics with a porosity that would allow the hydrodynamics of the ground-water system to enforce the trapping mechanisms.

Examples of hydrocarbon accumulation attributable to both structural and stratigraphic traps are present in the Slocum Fields in the southeastern portion of the study area. The Slocum Fields illustrate the complexity of structural and stratigraphic variations relating to hydrocarbon accumulations. The extent to which hydrodynamic forces enhance these traps has not been assessed. The Slocum Fields are all close to the Mt. Enterprise Fault Zone, which forms a graben system. Associated with the graben is Slocum Dome, a deep-seated salt dome 13 km (8 mi) long and 10 km (6 mi) wide (Read, 1959). Northwest Slocum (Woodbine) Field is a fault trap on three sides, with beds dipping away from the top of the dome forming the remainder of the trap. West Slocum (Woodbine) Field is similar except that a truncated sand pinchout forms one side of the trap. South Slocum (Woodbine) Field is an updip sand wedge-out into shale which dips away from the dome. Accumulation at the David-Gale (Sub-Clarksville) Field is the result of a Sub-Clarksville regional strand line intersecting the curvature of a salt dome to form a trap for hydrocarbons (Read, 1959).

Within the study area all currently reported production is from reservoirs generally composed of carbonates and sand-size clastics. Primary porosity is generally present in all sands and in some of the Cretaceous and Jurassic carbonates. However, most of the carbonates do not usually have significant primary porosity, and in producing fields carbonate porosity is generally attributed to secondary porosity developed by dolomitization. There is no reported production from gas caps associated with salt dome caprock in the area.

Porosity ranges for Woodbine reservoirs, which may or may not be similar for the sand reservoirs in other formations, are 10 to 20 percent. Carbonate reservoirs generally are less porous, with porosity ranges on the order of 5 to 15 percent. Similarly, there are significant differences in the gravity of hydrocarbons produced from the Upper Cretaceous compared to the Lower Cretaceous and Jurassic oils. The major proportion of the Upper Cretaceous Woodbine production is 10° to 70° API (American Petroleum Institute gravity rating) oil with a water drive, whereas the production of Lower Cretaceous Travis Peak and Jurassic is 35° to 60° API oil with a gas drive. The Tertiary Carrizo Formation generally does not produce, but in the Slocum Field area recovery is enhanced by steam injection, producing a lower gravity oil than the Woodbine, averaging 23° API.

As in most petroleum provinces, there have been three sequential stages of regional exploration in East Texas:

1. Exploration of obvious structural traps such as anticlines and salt domes
2. Exploration of combined structural and stratigraphic traps
3. Exploration of purely stratigraphic traps.

The current status of exploration in the study area is viewed as being transitional between the last two stages. Exploration trends for East Texas are gas oriented, with emphasis on deep Jurassic tests west of the study area on the western flank of the Northeast Texas Embayment. Within the study area there have been occasional deep exploration tests in the Lower Cretaceous Travis Peak and Jurassic, but these have met with limited success. Primary production within the study area is the result of expansion of existing fields along with development of exploration targets which were previously uneconomic. Development emphasis has been on the Upper and Lower Cretaceous horizons. Future exploration drilling within the study area will undoubtedly be limited by the economics of production, with possible areas of interest including:

1. Exploration of interdomal stratigraphic reservoirs
2. Shallow prospects in stratigraphic and structural traps from presently noncommercial horizons in the Tertiary and Cretaceous sections

(3) Deeper prospects for stratigraphic and structural traps in the untested Lower Cretaceous and Jurassic horizons
(4) Very deep prospects in the untested Paleozoic section.

6.3.2 LIGNITE: Lignite, a low-rank coal, is becoming a major energy resource in Texas. In the study area, currently commercial as well as potentially commercial quantities of lignite occur within the Wilcox Group as near-surface deposits, to 61 meters (200 ft) below the surface, and as deep-basin deposits greater than 61 meters (200 ft) below the surface.

The near-surface deposits occur along a band, following the outcrop pattern of the upper Wilcox, in the extreme western portion of the study area (Figure 6-36). These lignite seams, which have a maximum thickness of 1.5 to 4 meters (5 to 12 ft), are of deltaic origin and are considered potential resource deposits (Kaiser, 1974). Upper Wilcox deltaic lignites also outcrop concentrically around the Palestine Salt Dome in Anderson County, with a maximum seam thickness of 8 meters (25 ft). They were considered by Kaiser (1974) to be a principal lignite deposit and they were mined by Palestine Salt and Coal Company to supply the energy required for the brine operations at Palestine Dome. Lignite mining operations were suspended when the brine operations closed in the 1930's.

Deep-basin lignites occurring in the Wilcox Group are inferred from analysis of electric and induction well logs to be widely distributed throughout the study area (Kaiser, 1974). Very possibly, salt intrusion and related structural uplift could have brought deep-basin lignites in the Wilcox to within 61 meters (200 ft) of the surface, shallower than at localities not affected by doming. Evidence of the presence of deep-basin Wilcox lignites and the depths of these lignites at the study dome may be developed from the data produced from the field program. The commercial development of the deep-basin lignites would probably require some means of underground gasification because the depths of these deposits preclude the use of present surface mining practices.

Only limited lignite operations are currently active in the study area. Gasification operations involving deep-basin Wilcox lignite are being conducted in a prototype in situ gasification program operated by Basic Resources, Inc., about 11 km (7 mi) northwest of Palestine Dome in Anderson County. Open pit mining of near-surface lignite is under way at Big Brown Steam Plant in Freestone County on the northwest margin of the study area.

6.3.3. SALT: Salt is readily available by conventional extraction techniques from shallow salt domes, including Oakwood, Palestine, and Keechi within the study area, and Butler, Bethel, and Brushy Creek. Of these domes only Palestine has had commercial production, developed by the Palestine Salt and Coal Company; however, operations at Palestine were abandoned in the 1930's. Salt from these and other domes in the East Texas Salt Basin is believed to have a high relative purity of 98 percent sodium chloride, with the major impurity being anhydrite. Currently, no salt operations are active in the study area. Morton Salt

Company at Grand Saline Dome in Van Zandt County, 80 km (50 mi) north of the study area, is the only current producer of salt in the East Texas Salt Basin. The production volume is steady, apparently satisfying current demand. Accordingly, future production of salt in the study area is not anticipated without a substantial increase in demand.

6.3.4 STONE: Stone, as a mineral commodity, is currently being quarried by East Texas Stone of Corsicana, 10 km (6 mi) north of the town of Oakwood at Butler Salt Dome. The quarried stone is reported to be quartzitic sandstone and siltstone of the Upper Wilcox Group. Operations at the site have been active since 1954, with 1979 annual production estimated at 336,000 tonnes (300,000 tons). The quarried material is principally used locally as riprap and aggregate for concrete and asphaltic pavements.

6.3.5 OTHER RESOURCES: Other mineral resources in the study area (clay, peat, iron ore, rock aggregate, and sand and gravel) are neither produced nor considered a significant future resource. Such categories include clays of the Wilcox and Claiborne Groups and sand and gravels along the Trinity River which have a vast volume and areal extent. Other categories include mineral resources of a more localized nature which have had very limited, sporadic production because of poorly developed markets. This applies to the asphaltic sands of the Queen City Formation, 16 to 19 km (10 to 12 mi) east of Palestine and Keechi

Domes, potential peat deposits at Keechi Dome; iron ore deposits associated with outcrops of the Weches Formation throughout the study area; and the limestone rock aggregate associated with the Buda Formation exposed at Palestine Dome.

6.4 SUMMARY OF THE EAST TEXAS STUDY AREA

The East Texas Study Area is in the southern portion of the East Texas Salt Basin, which includes Keechi, Oakwood, and Palestine Domes. Although the geologic characterization studies were focused on the domes and the surrounding areas, the relationships and influences of the major elements of the geologic framework of the much larger East Texas Salt Basin are relevant.

Preexisting data, consisting of oil, gas and water well logs, seismic reflection surveys, regional residual gravity anomaly maps, and geologic maps, were purchased and evaluated. Data specifically acquired for this study consisted of deep and shallow borings and ground-level resistivity surveys over Oakwood Dome, field geologic mapping, remote sensing, and detailed gravity surveys and gravity models.

Isochores, structure contour maps, and stratigraphic cross section have been developed. These data, together with the surface geologic features, represent the basis from which the geologic evolution and actual geologic setting have been interpreted.

The physiography of the study area is strongly controlled by the regional structure and lithology of the stratigraphic units in the East Texas Basin. This relationship is modified by the

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presence of both shallow and deep salt masses. Movement of the Louann Salt, as a result of sediment loading, is believed responsible for controlling the location of the structural highs and the intervening subbasins. The development of salt structures appears to follow Trusheim's and Loocke's model of salt dome growth.

Mature domes, which have reached the burial stage of development, seem to occur along the subbasinal axes. The less mature domes, in the truncation stage, occur along the high axes or on their flanks. The various salt structures identified within the study area are in various stages of dome development and presumably, because the mechanism for further growth no longer exists, the salt masses appear to have been stabilized.

Most of the faulting in the study area can be characterized as minor, having been associated with salt movement. Major faulting, observed at the Mt. Enterprise Fault Zone, does not appear to be directly related to salt dome emplacement. Initial movement in the Mt. Enterprise Fault Zone occurred during the Lower Cretaceous, with maximum movement during Eocene and cessation of significant movement during late Pliocene.

The tectonic stability of the study area has been questioned by BEG on the basis of an attempt to correlate the following observations and interpretations:

(1) Minor faulting activity in nearby Quaternary terraces

(2) A modern change of elevation, 130 mm (5.1 in) down to the south of the Mt. Enterprise Fault Zone within a 30-year period, interpreted from published National Geodetic Survey data

(3) Several earthquakes with epicenters that have been reported in the vicinity of the Mt. Enterprise Fault Zone.

The overall evaluation of the data analyzed suggests that the study area is tectonically stable. Therefore, the aforementioned items need further investigation to determine relevance to the tectonic stability of the study area.

Major mineral resources of the study area are oil, gas, and lignites. Exploration and production of these resources are expected to continue with gas and lignite production increasing, whereas oil production is expected to decline at the fields near specific domes.

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7 GEOLOGIC CHARACTERIZATION OF SELECTED DOMES IN THE EAST TEXAS STUDY AREA

The studies discussed in this chapter focus on the areas within an 8-km (5-mi) radius of the candidate domes. Prior to the completion of the Area Characterization studies, ONWI directed that Palestine Dome be eliminated from further study because of unfavorable conditions (modern sinkhole development) reported by the Texas Bureau of Economic Geology. Therefore, the data base for Palestine Dome, being limited mainly to existing geological information, is not as complete as those developed for Keechi and Oakwood Domes.

Drilling at Oakwood Dome was curtailed before the field exploration was completed because it was feared that the existence of numerous exploration wells through the overhang of the dome could threaten the containment integrity of the dome. The work planned at Keechi was delayed in starting because of the questionable size of the dome. Four high-resolution seismic lines were originally planned to define the size and shape of Keechi Dome. Because of limited land access around the dome, only one high-resolution seismic line was obtained. As a result of excessive "noise" on the seismic record, little additional information was obtained (LETCo, 1981a). Exploration may resume at Keechi Dome if the seismic exploration program produces acceptable results regarding the size and shape of the dome. As a result of the sequence of events which slowed and eventually halted data gathering at the Texas domes, the data base is not as complete as those developed for the candidate domes in the Northern Louisiana and Mississippi Salt Basins.

7.1 OAKWOOD DOME

The surface area overlying Oakwood Dome is centered on the Freestone-Leon County line, approximately halfway between the towns of Buffalo and Oakwood. It is roughly circular in plan view, with a radius of 1.6 km (1 mi). Land ownership in the vicinity of the dome is predominantly private. Within a 3-km (2-mi) radius of the dome center there are about 30 property owners, one of whom controls about 60 percent of the area. The remainder of the area is about equally distributed among the other owners. Many inhabitants have seasonal or intermittent residency.

Population density in Freestone County, north of the dome, averages 15 to 20 inhabitants per square mile. Most of the population is centered around the larger towns of Fairfield (approximately 24 km (15 mi) northwest of Oakwood Dome) and Teague (approximately 25 km (16 mi) west-northwest of Oakwood Dome). In Leon County, south of the dome, population density is about 10 inhabitants per square mile, and the population is distributed mainly around the larger towns. The nearest permanent community to Oakwood Dome is Keechi (population less than 150), approximately 2.4 km (1.5 mi) to the southeast in Leon County.

A drilling program, planned and conducted by BEG and LETCo, developed data from a salt core hole and twenty shallow borings. Data from the salt core boring and shallow borings are in Table

7-1, and the locations are shown on Figure 7-1. Table 7-1 also includes data on the hydrocarbon wells drilled within the supradomal area. The LETCO numbers assigned to these wells correspond to a grid system developed to facilitate identification of the wells. The first letter identifies the dome, the first two digits correspond to the block numbers, while the last digit(s) indicate(s) the well identification number within each block. The Oakwood salt core hole, DOE Settlemyre TOG-1 (LETCo TOG-1), drilled to a depth of 413 meters (1,356 ft) [and its water supply well 183 meters (600 ft) deep], provided new data on the composition of domal material and sediments overlying the dome.

The water supply well at TOG-1 was also used to provide data for evaluation of hydrologic properties of fresh water aquifers overlying the dome. The (20) shallow borings, varying in depth from 15 to 136 meters (50 to 445 ft), were drilled to evaluate stratigraphic and structural relations of surface beds over the dome where the mapping was hampered by poor outcrops. Five hydrologic test wells were also drilled to evaluate hydrologic properties of fresh water aquifers at the domal flanks and to provide data for geologic studies (see Figures 7-1 and 7-5, and Appendix).

7.1.1 DOME GEOMETRY AND COMPOSITION: Gravity modeling of Oakwood Dome indicates that the longitudinal profile resembles a bulb shape, and in plan view it is nearly circular (Figure 7-1). The bulb form is caused by a slight overhang that extends completely around the upper portion of the dome, reaching a maximum

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TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY

WELL NAME	LETCO WELL NO.	LOCATION	ELEV. (MSL)* G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.—DEPTH	GROUTING†	CASING SEAT DEPTH (FT)	ABANDONMENT PROCEDURE	Elev. (MSL)** TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL)** TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
McBee #1-A Campbell 1st hole	015-1	330' FNEL & 330' FNWL of Real Surv 3 mi. NW of Keechi in Freestone Co.	+418 (DF)	1900	None	16" @ 150' 10 3/4" @ 1395' 8 5/8" @ 1720'	150 sx cmt† 1250 sx cmt 625 sx cmt	150 1395 1720	Lost Circulation. Plugged back to surface	-722'/514	-1236/?	Texas Bureau of Economic Geology Completion Cards	Abandoned
2nd hole		150' W of 1st hole	+418 (DF)	11,119	Electric dipmeter Sonic	20' @ 135' 13 3/8" @ 2110' 9 5/8" @ 2434' 7" @ 10,338'	No Data	135 2110 2434 10,338	Pulled out 7" casing & plugged back with cement to 5450'.	-792'/760	-1552/4030	Geoph. logs, Scout ticket	Abandoned
1st sidetrack		as above		Fr. 5398 to 6400 TD	None	None	No Data	None	Plugged back with cement to 3250'	as above	as above		Abandoned
2nd sidetrack		as above		Fr. 3200 to 6344 TD	Electric & Directional	None	No Data	None	Plugged back to surface	as above	as above		Abandoned
McBee #1 Campbell Gas Unit	015-5	330' FNEL & 330' FNWL of R. Real Surv. 3 mi. NW of Keechi in Freestone Co.	+422 (KB)	1395	Radioactivity & Temperature	16" @ 136' 10 3/4" @ 1395'	150 sx cmt 600 sx cmt	136 1395	Lost circulation, pumped about 5000 sx cement to plug hole. Set 103/4" casing plug at 1380' and plugged back to surface.	Not Encountered	Not Encountered	Geoph. logs, TBEG, Plugging Data	Abandoned
Texaco #1 Marshall OH	015-2	In W.T. Cooper Surv (A-717) 410' FSEL 150' FNEL of surv	+415 (DF)	5764	Continuous Dipmeter, Laterolog, Gamma Ray	16" @ 105' 10 3/4" @ 1050'	No Data No Data	105 1050	No Data	No Data	-805/4509		Abandoned
1st sidetrack		as above		5913	Laterolog, Dipmeter, Gamma Ray	16" @ 105' 10 3/4" @ 1050' 7 7/8" @ 5913'	No Data	105 1050 5913	No Data	No Data	as above	Geoph. logs, TBEG, Scout ticket	Abandoned
2nd sidetrack		as above		6137	Laterolog	None	No Data	None	No Data	No Data	as above		Abandoned
3rd sidetrack		as above		5087	None	None	No Data	None	No Data	No Data	as above		Abandoned
McBee #4 Settleayre	016-16	In W. Penman Surv (A-831) 1050' FSWL & 1230' FN'LY SEL	+445	2320	Sample log	No Data	No Data	No Data	No Data	-1645/60	-1705	TBEG, Well Completion Report, Sample log	Abandoned
Texaco #6 Settleayre (Sidetrack data on next page)	016-18	In W. Penman Surv (A-831) 760' FSEL & 751' FSWL 6 MI SE of Langley	+424	5845	Sonic, Laterolog, Gamma Ray, Formation Test, Dipmeter	16" @ 43' 10 3/4" @ 1033'	2 yds concrete 500 sx cmt 200 sx cmt	43 1033	Put in 100 sacks cement @ 5845'. Drilled out cement to 5177' then 100 more sacks added. Then drilled out cement to 4935' & set whip stock to drill sidetrack.	No Data	-804/4137	Geoph. logs, Texas RR Commission Report, Well Completion Report	Abandoned

* Ground Level, unless Otherwise Indicated; DF = Derrick Floor; KB = Kelly Bushing

** Elevations of caprock and salt as given in well documentation, i.e. not corrected to ground level where elevation is given from derrick floor or Kelly bushing.

† sx cmt = sacks cement

OH: Original Hole

TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY (CONTINUED)

WELL NAME	LETCO WELL NO.	LOCATION	ELEV.(MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.--DEPTH	GROUTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
Texaco #6 Settlemyre 1st sidetrack	016-18	In W. Penman Sur A-831 760' FSEL & 751' FSWL. 6 mi. SE of Langley	+424	5753	Sonic, Laterolog, Gamma-Ray, Formation Test, Dipmeter	4 1/2" @ 5753' 2 3/8" @ 5500'	195 sx cmt	5753	Producing well.	No Data	as above	Geoph. logs, Texas Railroad Commission Report, Well Report	Oil producer
McBee #2 Settlemyre	016-15	In W. Penman Sur A-831 660' FSWL & 400' FSEL of survey	+430 (DF)	1435	Sample log	9 5/8" @ 313'	No Data	313	No Data	-600/270	-870/ To Bottom	Sample log, TBEG	Abandoned
McBee #3 Settlemyre	Not in file	In W. Penman Sur A-831 approx. 500' FSEL & 1200' FSWL (plotted from base map)	+435 (DF)	No Data	No Data	No Data	No Data		No Data	-573/221	-794/ To Bottom	TBEG	Abandoned
McBee #C-1 Settlemyre OH	016-6	In W. Penman Sur A-831 approx. 220' FSEL & 1100' FSWL of surv.	+436	5788	Electric	9 5/8" @ 1239'	No Data	1239	Cement plug at 4192	No Data	-797/4226	TBEG, Geoph. logs, Scout sheet	Abandoned
1st sidetrack				5802	Electric	None set.	No Data	No Data	No Data	No Data	as above		Abandoned
2nd sidetrack				5765	Electric, Sonic	5 1/2"	No Data	No Data	No Data	No Data	as above		Oil producer
Texaco #5 Settlemyre OH	016-5	H. H. Heatly Surv. A-311 160' FNWL, 1200' FNEL of surv.	+447 (KB)	5838	Electric	16" @ 79' 10 3/4" @ 1043'	No Data	79 1043	Set cement plug from 4050' to 4350'.	-651/163	-814/4179	Scout sheet, geoph. logs, scout ticket completion card	Abandoned
1st sidetrack				5850	Electric, Micro log	4 1/2" @ 5850'	No Data	5850	No Data	as above	as above	Completion report	Oil producer
Texaco #4 Settlemyre	016-3	H. H. Heatly Surv. 570' FNWL & 630' FNEL of survey.	+458 (KB)	5850	Caliper, Elec. log, Micro log	16" @ 77' 10 3/4" @ 1027' 8 5/8" from 967'-1334' 5 1/2" @ 5850'	No Data	77 1027 1334 5850	No Data	No Data	-812/4050	TBEG, geoph. logs, Scout ticket, completion card	Oil producer
Texaco #3 Settlemyre (Sidetrack Data on next page) OH	016-4	H. H. Heatly Surv. 1160' FNWL & 290' FNEL.	+460 (DF)	5806	Elec. log, Micro log	16" @ 106' 10 3/4" @ 1081'	120 sx cmt 425 sx cmt	106 1081	Plugged back to 4535' set whipstock to drill sidetrack.	-650/152	-802/4119	TBEG, scout sheet, completion report, geoph. logs	

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TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY (CONTINUED)

WELL NAME	LETCO WELL NO.	LOCATION	ELEV.(MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.—DEPTH	GROUTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
Texaco #3 Settlemyre 1st sidetrack	016-4	R.B. Neatly Surv. 1160' FNL & 290' FWEL.	+460 (DF)	5847	Electric Microelectrical	5 1/2" @ 5846'	No Data	5846	No Data	Same as Texaco Settlemyre #3	-892/4128	Same as Texaco Settlemyre #3	Oil producer
Texaco #1 Settlemyre GM	016-19	R.B. Neatly Surv. A-311 467' FSEL & 1000' FNEL of surv.	+412 (KB)	6500	Electric	16" @ 86' 10 3/4" @ 1222'	45 sx cmt 440 sx cmt	86 1222	Plugged back to 1744' & set whipstock to drill sidetrack	No Data	-806/4537	Scout ticket, geoph. logs, Completion card, TBEG	Drilled in 1957. Abandoned
1st sidetrack				6568	Electric	5 1/2" @ 6032'	No Data	6032	No Data	No Data	Same as above		Abandoned
McBee #1-D Settlemyre	016-2	R.B. Neatly Surv. A-311 467' FSEL & 1100' FNEL of surv.	+418 (KB)	10,215	Laterolog, Diplog, Densilog, Gamma Ray	as above; No more casing added	None	None	No Data	No Data	Same as above	TBEG, scout sheet, geoph. logs	Drilled in 1976 Abandoned
McBee #1-B Settlemyre GM	016-7	Pennman Surv. A-831 2-1/2 Mi. N/ Keechi, start at SE/L of Neatly Surv. & go NW along NEL of Surv., 1080' thence NE at RA 200' to location	+463	5813	Electric, Sonic Gamma Ray, Driller's log, Directional	9 5/8" @ 1360' 5 1/2" @ 5813'	No Data	1360 5813	Produced, oil, later went back in hole, cut off old csg. @ 4815' then sidetracked to 5740'	No Data	-806/3948	Scout tickets, geoph. logs, Completion card, TBEG	Oil producer. Drilled in 1959. Abandoned in 1964.
1st sidetrack				5740		5 1/2" @ 5740'	No Data	5740	No Data	No Data	Same as above		Oil producer. Drilled in 1964.
Texaco Settlemyre #1 Well #2	016-8	W.D. Allison Surv. A-790 90' FSWL & 1060' FSEL of sur.	+432	5840	Electric	16" @ 90' 10 3/4" @ 1071' 8 5/8" @ 1608'	No Data	90 1071 1608	No Data	No Data	Bottom salt @ -4818 MSL	TBEG, scout sheet, geoph. logs	Aband- ed
1st sidetrack				5800	Electric, Laterolog, Formation Test.	5 1/2" @ 5799'	No Data	5799	No Data	No Data	Bottom salt @ -4883 MSL		Oil producer.
McBee #5 Settlemyre GM	016-1	W.D. Allison Surv. 330' FWL & 330' FSL.	+370	5760	Electric, Directional, Microelectrical	16" @ 138' 9 5/8" @ 1188' 5 1/2" @ 5760	100 sx cmt 300 sx cmt 100 sx cmt	138 1188 5760	No Data	-651/156	-807/4005	TBEG, scout sheet, geoph. logs, well record	Oil producer.
1st sidetrack				5700	Electric, Sonic, Neutron	5 1/2" @ 5700'	No Data	5700	No Data	As above	As above		Oil producer.
Texaco #1 Rabe	016-9	T.J. Teal Surv. A-774 900' W of Freestone/Leon Co Line. 1177' FNL of Survey. 2 Mi NW of Keechi.	+400 (DF)	5863	Electric, Laterolog, Microlog	16" @ 1090' 10 3/4" @ 1232' 5 1/2" @ 5826'	No Data 550 sx 273 sx	1090 1232 5826	No Data	-690/100	-790/4095	TBEG, scout sheet, geoph. logs, completion card	Oil producer; Permit granted 6/68 to inject inert gas into Woodbine @ 5650' depth, but cancelled after 12/72 inspection indicated no injection had ever taken place.

TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY
(CONTINUED)

WELL NAME	LETCO WELL NO.	LOCATION	ELEV. (MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.—DEPTH	GROUTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
Texas Co. #2 Rabe	016-10	T.J. Teal Surv. 1400' FNWL, 1370' FNEL of sur.	+423 (DF)	6115	Electric	10 3/4" @ 1239'	No Data	1239	Plugged back to 3300' & side-tracked.	-667/128	-795/4042	TBEG, geoph. logs, formation record, completion card	Abandoned
1st sidetrack				5925	Electric	None	No Data	No Data	Plugged back to 4186' & side-tracked.				Abandoned
2nd sidetrack				5799	Electric	None	No Data	No Data	Plugged back to 2868' & side-tracked.				Abandoned
3rd sidetrack				5857	Electric	None	No Data	No Data	Plugged back to 4000' & side-tracked.				Abandoned
4th sidetrack				5891.5	Electric	5 1/2" @ 5890'	No Data	5890	No Data				Oil producer.
Texaco #3 Rabe	016-17	T.J. Teal Surv. 1120' FNEL & 870' FSEL of surv.	+420	10,595	Electric, Induction Electrical, Microlog Laterolog, Sonic, Directional	16" @ 65' 10 3/4" @ 1139' 7 5/8" @ 6273' 4 1/2" @ 6371 2 3/8" @ 5659'	No Data 696 sx 375 sx	65 1139 6273 6371 5659	Still producing	-708/94	-802/4128	TBEG, geoph. logs, Texas Railroad Commission report	Dual completion Oil producer; permit granted 6/68 to inject inert gas into Woodbine @ 5744' depth, but cancelled after 12/72 inspection indicated no injection had ever taken place.
Hughey #1 Coleman	021-10	A. McKinnon Surv. A-1329 113' FSWL 130' FNWL in block 27.	+425 (DF)	5732	Gamma Ray, Neutron	10 3/4" @ 1046' 8 5/8" @ 990-1389 4 1/2" @ 573'	No Data	1046 1389 573	Still producing	No Data	-1711/3551	TBEG, geoph. logs, scout sheet, Texas RR Comm report	Oil producer
Carter-Jones #2 Coleman	021-13	A. McKinnon Surv. A-1329 69' FWSL & 225' FNWL of block 27	+424 (DF)	5676	Laterolog	9 5/8" @ 1269' 5 1/2" @ 5680'	No Data	1269 5680	Converted to a Brine-Disposal Well in 1964	No Data	Bottom of Salt @ -4958	TBEG, scout sheet, geoph. log, Texas RR Comm form W-14	Brine-Disposal Well, disposal depth from 1271 to 1280' (Woodbine Fm.) at approx. 200 P.S.I. Disposal rate: 36,500 to 73,000 barrels/yr.
Carter-Jones #1 Coleman	021-9	A. McKinnon Surv. 390' FNWL, 113' FSWL of block 27	+424 (DF)	5812	Gamma Ray, Laterolog	10 3/4" @ 1040'	No Data	1040	Plugged back to 4525' & side-tracked.	No Data	-976/3895	TBEG, scout sheet, geoph. log	Abandoned
1st sidetrack				5750	Laterolog	None	No Data	None	Plugged back to 5277' & side-tracked.	No Data	As above		Abandoned
2nd sidetrack				5720	None	None	No Data	None	Plgd. back to 5277' & side-tracked.	No Data	As above		Abandoned
3rd sidetrack				5660	Laterolog	5 1/2" @ 5660'	No Data	5660	No Data	No Data	As above		Oil producer

98

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TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY
(CONTINUED)

WELL NAME	LETCH WELL NO.	LOCATION	ELEV. (MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.—DEPTH	CEMENTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
Hughey #1 Pickard	021-12	A. McKinnon Surv. 572' FNWL & 600' NE'LY SWL of Surv.	+426 (KB)	5743	Electric	10 3/4" @ 1014' 8 5/8" @ 1320'	No Data	1014 1320	Plugged back to 4000' & sidetracked.	No Data	Bottom Salt at about -4820	TBEG, geoph. logs, scout sheet	Abandoned
1st sidetrack				5819	Electric	None	No Data	None	Plugged back to 4600' & sidetracked.	No Data	No Data		Abandoned
2nd sidetrack				5723	Electric	5 1/2" @ 5722'	No Data	5722	No Data	No Data	No Data		Oil producer; permit to convert to salt-water disposal well from 1260' to 1268' depth granted 5/68 (up to 500 bbls/day by gravity injection).
Hughey #1 Stanton	021-11	A. McKinnon Surv. 250' FEL, 40' FSL of block #12.	+413	5800	Electric	10 3/4" @ 1002'	No Data	1002	Plugged back to 4845' & sidetracked.	-684/106	-780/4002	TBEG, scout sheet, geoph. logs	Abandoned
1st sidetrack				5725	Caliper	5 1/2" @ 5724'	No Data	5724	No Data	As above	As above		Oil producer
Texaco Detroit Oil Unit #1 CM	021-17	A. McKinnon Surv. 950' FNWL & 309' FSWL of surv.	+403	5775	Electrolog	16" @ 71' 10 3/4" @ 996' 5 1/2" @ 5774'	No Data	71 996 5774	Set plug from 4630' to 4890' & sidetracked.	-704/85	-789/4060	TBEG, scout sheet, geoph. logs	Oil producer
1st sidetrack				5800	Electrolog	No Data	No Data	No Data	No Data	As above	As above		Oil producer
Texaco #8-1 Keechi	021-16	W. Feller Surv. 50' FEL, 1517' FSL of 328 acre tract	+370 (DF)	5775	Dipmeter, Microelectrical, and others	10 3/4" @ 1005' 8 5/8" Liner @ 1282' 5 1/2" @ 5770'	No Data	1005 1282 5770	No Data	No Data	-890/4043	Scout sheet, TBEG, geoph. logs, completion card.	Oil producer
Texaco #4 Keechi Pet. CM	021-6	W. Feller Surv. 250' FSEL & 63' FNEL of surv.	+382 (DF)	5750	Electric	10 3/4" @ 946' 5 1/2" @ 5748'	No Data	946 5749	No Data	No Data	-853/4043	Scout sheet comp. card, geoph. logs, TBEG	Oil producer
McBee #1 Sherman CM	021-3	W. Feller Surv. 115' FNEL, 2270' FSEL of surv.	+396	6612	Electric	13 3/8" @ 120'	No Data	120	Plugged back & sidetracked	-627/837	-1464/To Bottom	Scout sheet, completion card, geoph. log, TBEG	Abandoned
1st sidetrack				6184	Electric	None	No Data	None	Plugged back to 4900' & sidetracked.	As above	As above; Bottom Salt @ -4926		Abandoned
2nd sidetrack				5770	Electric	5 1/2" @ 5769'	No Data	5769	Plugged back to 5965'& sidetracked.	As above	As above		Oil producer
3rd sidetrack				5725	Induction Electrical	4" @ 5725'	No Data	5725	No Data	As above	As above		Oil producer
4th sidetrack				5728	Electric	No Data	No Data	No Data	No Data	As above	As above		Oil producer

TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY (CONTINUED)

WELL NAME	LETCO WELL NO.	LOCATION	ELEV. (MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.--DEPTH	GROUTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
Texas Co. #1 Keechi Pet. ON	021-4	W. Feller Surv. A-274, 1300' FSL & 600' FEL of surv.	+354	6090	Electric	16" @ 83' 10 3/4" @ 118' 8 5/8" @ 1325'	No Data	83 118 1325	Plugged back to 3650' & side-tracked.	-711/90	-801/4163	Scout sheet, completion card, geoph. log TBEG	Abandoned
1st sidetrack				5212	None	None	No Data	None	Crooked hole, pluged back to 5132' & side-tracked.	As above	As above		Abandoned
2nd sidetrack				5892	None	None	No Data	None	Plugged back to 4520' & side-tracked.	As above	As above		Abandoned
3rd sidetrack				5748	Electric	5 1/2" @ 5748'	No Data	5748	No Data	As above	As above		Oil producer
Texas Co. #2 Keechi	021-15	W. Feller Surv. 1200' FNEL & 1015' FSEL of surv.	+374 (DF)	5832	Electric	16" @ 120' 10 3/4" @ 997' 8 5/8" @ 1280'	No Data 400 sx 675 sx	120 1280 997	Plugged back to 4211' & side-tracked.	No Data	Bottom Salt at about -5166 MSL	Scout sheet, completion card, geoph. logs, TBEG	Abandoned
1st sidetrack				5752	Microelectric, Laterolog	5 1/2" @ 5748'	165 sx	5750	No Data	-796/	-1301/3765		Oil producer; permit granted in 6/68 to inject inert gas into Woodbine at 5640' depth, but cancelled after 12/72 inspection indicated no injection had ever taken place.
Texaco #3 Keechi ON	021-5	W. Feller Surv. 1900' FNEL, 835' FSEL of surv.	+335 (KB)	5700	Electric	16" @ 60' 10 3/4" @ 942' 8 5/8" @ 942' to 1200'	No Data	60 942 1200	Plugged back to 4330' & side-tracked.	No Data	-805/4177	TBEG, scout sheet, geoph. logs, completion card	Abandoned
1st sidetrack				5680	Induction Microelectrical	None	No Data	None	Plugged back to 4615' & side-tracked.	No Data	As above		Abandoned
2nd sidetrack				5723	Electric	4 1/2" @ 5722'	No Data	5722	No Data	No Data	As above		Oil producer
Pickens Scates #1 'estor ON	021-2	W. Feller Surv. 758' FSEL & 135' FSEL of surv.	+332 (KB)	5704	Electric, Microlateral, Neutron	16" @ 65' 10 3/4" @ 830' 8 5/8" @ 1208'	No Data	65 830 1208	Plugged back to 4500' & side-tracked.	No Data	-880/4097	TBEG, scout sheet, completion card, geoph. logs	Abandoned
1st sidetrack				5663	Electric	None	No Data	None	Plugged back to 4650' & side-tracked.	No Data	As above		Abandoned
2nd sidetrack				5760	Electric, Neutron	None	No Data	None	Plugged back to 4300' & side-tracked.	No Data	As above		Abandoned
3rd sidetrack				5662	Electric, Neutron	None	No Data	None	Plugged back to 3726' & side-tracked.	No Data	As above		Abandoned
4th sidetrack				5667	Electric	5 1/2" @ 5667'	No Data	5667	Pulled casing, plugged back & sidetracked.	No Data	As above		Abandoned
5th sidetrack				5632	No Data	No Data	No Data	No Data	No Data	No Data	Salt thickens at -4213 MSL		Abandoned

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TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY (CONTINUED)

WELL NAME	LETCO WELL NO.	LOCATION	ELEV. (MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.--DEPTH	GROUTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
McBee #1 McBrayne CH	021-8	A. McKinnon Surv. A-1332 330' FEL 330' FNL of McBrayne Lease	+374 (KB)	6045	Electric	13 3/8" @ 62' 9 5/8" @ 1239'	30 sx cmt 800 sx cmt	62 1239	Plugged back to 3063' & side-tracked.	No Data	-975/4415	Geoph. logs, TBEG, scout sheet, completion card	Abandoned
1st sdtk.				5777	None	None	None	None	Plugged back to 3812' & side-tracked.	No Data	As above		Abandoned
2nd sdtk.				5779	None	None	None	None	Plugged back to 4941' & side-tracked.	No Data	As above		Abandoned
3rd sdtk.				5799	Electric	None	None	None	Plugged back to 2100' & side-tracked.	No Data	As above		Abandoned
4th sdtk.				5710	Electric	5 1/2" @ 5704'	150 sx cmt	5704	No Data	No Data	As above		Oil producer
Shell (McBee) #1 Tinsley CH	022-1	H.D. Gamble Surv. A-678 1000' FNWL, 775' FNEL of sur.	+400 (DF)	6500	Induction Electrical, Gamma Ray, Neutron	13 3/8" @ 89'	100 sx cmt	89	Plugged back; sidetracked.	No Data	-865/To Bottom	Geoph. logs, completion card, TBEG	Abandoned
1st sdtk.				6350	Laterolog, Gamma Ray, Micro-Lateral	None	None	None	Plugged back; sidetracked.	No Data	-865/4444		Abandoned
2nd sdtk.				No Data	Electric	No Data	No Data	No Data	No Data	No Data	No Data		Abandoned
McBee #1 Marie Storms	022-3	H.D. Gamble Surv. A-678 1450' FNWL & 750' FSSWL	+366	6012	Gamma Ray, Laterolog, Dipmeter, Sample log	13 3/8" @ 45'	60 sx cmt	45	No Data	-1557/20	-1577/1767	Geoph. logs, completion card, scout sheet, sample log, TBEG	Abandoned
Rosanna #1 Marshall	022-5	D. Marshall Surv. A-897 100' FSWL 150' FNEL	(approx) +440	877	Driller's log	12 1/2" @ 42'	No Data	42	No Data	-427/To Bottom	Salt not encountered	Driller's log	Abandoned
DOE Settlemyre TOG-1	TOG-1	H. Cooper Surv.	(approx) +356	1356	Dual Induction Temperature, sonic, sample log, Microlaterolog, X-Y Caliper, Microelectrical, density, neutron, density, Gamma Ray, Repeat Formation Tester Dipmeter	16" @ 57' 12 3/4" @ 350' 9 5/8" @ 720'	215 sx cmt 125 sx cmt 275 sx cmt	350	Cement plug: 175 sacks bet. 1356' & 1110'; 60 sx fr 670' to 770' 10 sx fr 0' to 10'	337/450	-807/To Bottom	Geoph. logs, sample log, daily driller's report	Abandoned

TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY (CONTINUED)

WELL NAME	LETCO WELL NO.	LOCATION	ELEV. (MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.—DEPTH	GROUTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
DOE Settlemyre TOO-1WS	TOG-1WS	H. Cooper Surv. A-677	(approx) +356	600	Dual Induction, X-Y Caliper, Caliper, Sonic Bond	13 3/8" @ 65' 6 5/8" @ 104'	215 sx cmt 50 sx cmt	65	Plugged back to 180' produced water fr. 104' to 165'	Caprock not encountered	Salt not encountered	Geoph. logs	Producing water Carrizo sand
LETCO Shallow Boring	TOE-101	R. Heatley Surv. A-311	(approx) +410	250	Gamma Ray, SP, Resistivity	4 1/2" @ 212' 4 1/2" screen @ 222'	375 gal. grout	212 222	Hydrologic Observation well	Caprock not encountered	Salt not encountered	Geoph. logs, completion report, sample log	Hydrologic Observation well
LETCO Shallow Boring	TOE-102	H. Cooper Surv. A-677	(approx) +370	300	Gamma Ray, Resistivity Sonic Bond, Calipermal,	4 1/2" @ 140' 4 1/2" screen @ 150' 4 1/2" Tailpipe @ 160	375 gal. grout	140 150	Plugged back to 160'	Caprock not encountered	Salt not encountered	Geoph. logs, sample log, completion report	Hydrologic Observation well
LETCO Shallow Boring	TOE-103	T. Teal Surv. A-774	(approx) +385	300	SP, Gamma Ray, Resistivity	4 1/2" @ 232' 4 1/2" screen @ 242'	395 gal. grout	232 242	Plugged back to 245'	Caprock not encountered	Salt not encountered	Geoph. logs, sample log, completion report	Hydrologic Observation well
LETCO Shallow Boring	TOE-104	T. Teal Surv. A-774	(approx) +385	240	SP, Gamma Ray, Resistivity	4 1/2" @ 172' 4 1/2" screen @ 182'	285 gal. grout	172 182	Plugged back to 182'	Caprock not encountered	Salt not encountered	Geoph. logs, sample log completion report	Hydrologic Observation well
LETCO Shallow Boring	TOE-105	W. Feller Surv. A-274	(approx) +330	300	SP, Gamma Ray, Resistivity	4 1/2" @ 80' 4 1/2" screen @ 90'	110 gal. grout	80 90	Plugged back to 90'	Caprock not encountered	Salt not encountered	Geoph. logs, sample log, completion report	Hydrologic Observation well
LETCO Shallow Boring	TOE-106	W. Feller Surv. A-274	(approx) +360	300	SP, Gamma Ray, Resistivity	4 1/2" @ 242' 4 1/2" screen @ 252'	407 gal. grout	242 252	Plugged back to 255'	Caprock not encountered	Salt not encountered	Geoph. logs, sample log, completion report	Hydrologic Observation well
LETCO Shallow Boring	TOE-107	A. McKinnon Surv. A-884	(approx) +365	214	SP, Gamma Ray, Resistivity	4 1/2" @ 190' 4 1/2" screen @ 200'	320 gal. grout	190 200	Plugged back to 200'	Caprock not encountered	Salt not encountered	Geoph. logs, sample log, completion report	Hydrologic Observation well
LETCO Shallow Boring	TOE-108	A. McKinnon Surv. A-884	(approx) +370	320	SP, Gamma Ray, Resistivity	4 1/2" @ 300' 4 1/2" screen @ 310'	540 gal. grout	300 310	Hydrologic Observation well	Caprock not encountered	Salt not encountered	Geoph. logs, sample logs, completion report	Hydrologic Observation well

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TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY
(CONTINUED)

WELL NAME	LETCO WELL NO.	LOCATION	ELEV. (MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.—DEPTH	GROUTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
LETCo Shallow Boring	TOE-109	W. Feller Surv. A-274	(approx) +330	50	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geph. logs	Abandoned
LETCo Shallow Boring	TOE-110	W. Feller Surv. A-274	(approx) +330	50	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geoph. logs	Abandoned
LETCo Shallow Boring	TOE-111	W. Feller Surv. A-274	(approx) +325	50	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geoph. logs	Abandoned
LETCo Shallow Boring	TOE-112	W. Feller Surv. A-274	(approx) +355	50	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geoph. logs	Abandoned
LETCo Shallow Boring	TOE-113	W. Feller Surv. A-274	(approx) +365	60	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geoph. logs	Abandoned
LETCo Shallow Boring	TOE-114	W. Feller Surv. A-274	(approx) +360	50	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geoph. logs	Abandoned
LETCo Shallow Boring	TOE-115	Brown Surv. A-82	(approx) +310	445	SP, Gamma Ray, Single Pt. Resist., 16" Normal Resist.	4 1/2" @ 387' 4 1/2" screen @ 397'	660 gal. grout	387 397	Hydrologic Observation well	Caprock not encountered	Salt not encountered	Geoph. logs	Observation well
LETCo Shallow Boring	TOE-117	W. Feller Surv. A-274	(approx) +350	50	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geoph. logs	Abandoned
LETCo Shallow Boring	TOE-118	W. Feller Surv. A-274	(approx) +355	50	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geoph. logs	Abandoned
LETCo Shallow Boring	TOE-119	D. McKinnon Surv.	(approx) +355	300	SP, Gamma Ray, Resistivity	4 1/2" @ 206' 4 1/2" screen @ 216'	360 gal. grout	206 216	Hydrologic Observation well	Caprock not encountered	Salt not encountered	Geoph. logs, completion report, sample logs	Observation well
LETCo Shallow Boring	TOE-120	W. Feller Surv. A-274	(approx) +340	50	SP, Gamma Ray, Resistivity	None	None	None	Plugged back to surface	Caprock not encountered	Salt not encountered	Geoph. logs	Abandoned

TABLE 7-1

OAKWOOD DOME BOREHOLE DATA SUMMARY
(CONTINUED)

WELL NAME	LETCO WELL NO.	LOCATION	ELEV. (MSL) G. L. (ft)	TOTAL DEPTH (ft)	LOGS RUN	CASING DIA. O.D.--DEPTH	GROUTING	CASING SEAT DEPTH (ft)	ABANDONMENT PROCEDURE	Elev. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (ft)	Elev. (MSL) TOP SALT/ THICKNESS PENETRATED (ft)	SOURCE	REMARKS
LETCo Shallow Boring	TOE-121	H. Gamble Surv. A-1405	(approx) +440'	300	SP, Gamma Ray, Resistivity	4 1/2" @ 62' 4 1/2" screen @ 72'	90 gal. grout	62 72	Plugged back to 75'	Caprock not encountered	Salt not encountered	Geoph. logs, sample log, completion report	Observation well

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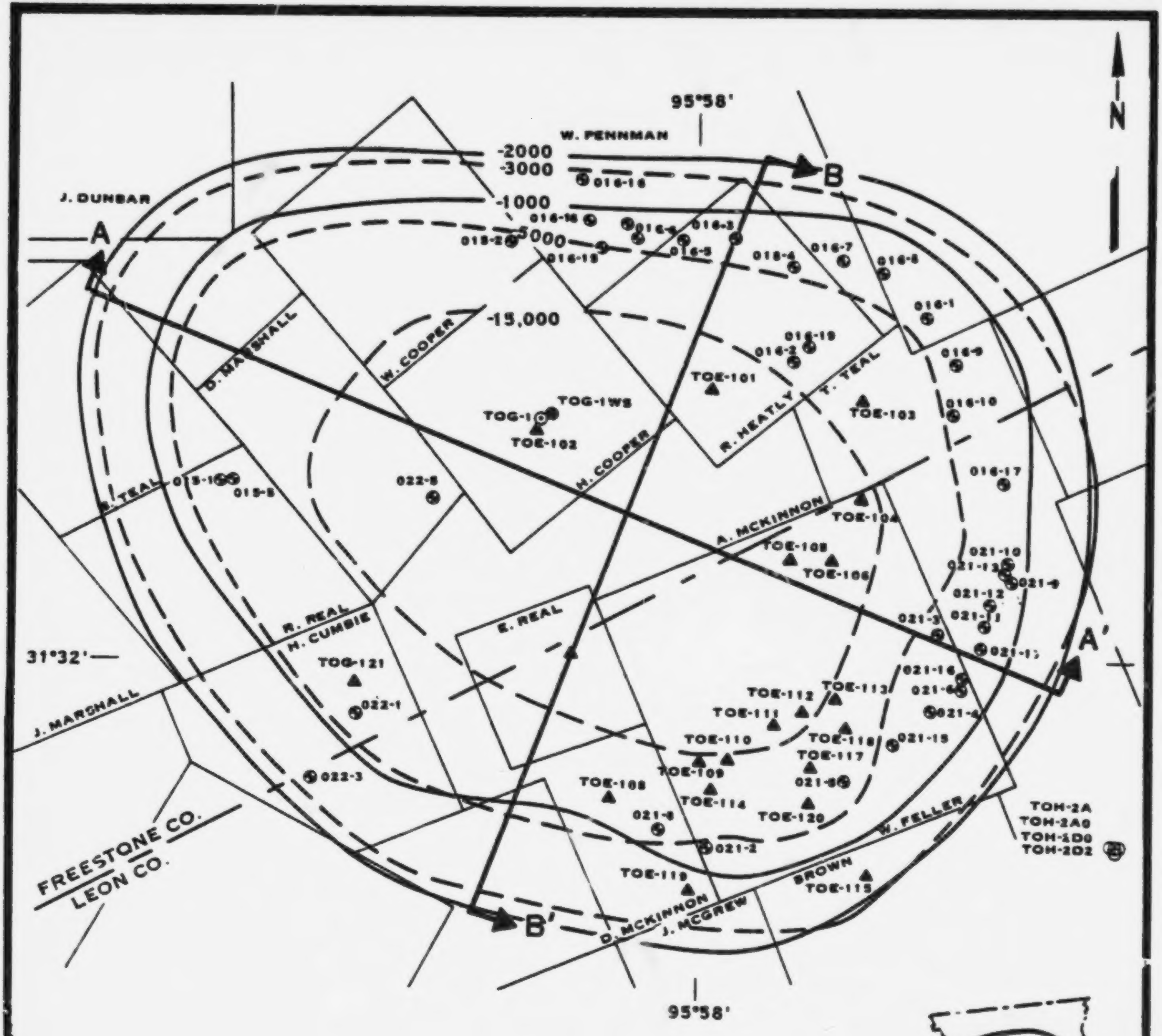

N
95°58'
W. PENNMAN
-2000
-3000
-1000
-5000
-15,000
B
A
J. DUNBAR
016-16
016-18
016-6
016-3
015-2
016-15
016-5
016-4
016-7
016-8
016-1
016-19
016-2
016-9
016-10
016-17
D. MARSHALL
W. COOPER
TOG-1WS
TOG-1
TOE-102
TOE-101
H. COOPER
R. HEATLY
T. TEAL
TOE-103
S. TEAL
015-1
015-5
022-5
A. McKINNON
TOE-104
TOE-105
TOE-106
021-10
021-13
021-9
021-12
021-11
021-3
021-17
A'
31°32'
R. REAL
H. CUMBIE
E. REAL
TOG-121
022-1
J. MARSHALL
021-16
021-6
021-4
TOE-112
TOE-113
TOE-111
TOE-110
TOE-116
021-15
TOE-117
TOE-109
021-5
022-3
TOE-108
TOE-114
TOE-120
021-8
021-2
W. FELLER
TOH-2A
TOH-2A0
TOH-2D0
TOH-2D2
FREESTONE CO.
LEON CO.
TOE-119
BROWN
TOE-115
B'
D. McKINNON
J. McGREW
95°58'

OAKWOOD DOME
STUDY AREA

LEGEND

●	HYDROCARBON WELL, WELL KEY IN TABLE 7-1
○	AREA CHARACTERIZATION HYDROLOGIC BORING
●	AREA CHARACTERIZATION GEOLOGIC BORING
⊙	AREA CHARACTERIZATION SALT CORE BORING
▲	AREA CHARACTERIZATION SHALLOW BORING
— -2000 —	LINE OF EQUAL ELEVATION OF SALT DASHED BENEATH OVERHANG. INTERVAL IS 1000 FEET. DATUM IS MEAN SEA LEVEL.

2000 0 2000 FEET

500 0 500 METERS

PREPARED ___ DATE ___
REVISED ___ DATE ___
REVISED ___ DATE ___
APPROVED ___ DATE ___
T-1108-1

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STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

OAKWOOD DOME
SALT STRUCTURE AND
WELL LOCATION MAP
JOB NO. MV9600 FIGURE 7-1

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105

diameter of about 3,962 meters (13,000 ft) at approximately -610 meters (-2,000 ft) MSL. With depth, the diameter of the dome decreases until -3,048 meters (-10,000 ft) MSL, where it reaches a relatively constant diameter of about 2,134 meters (7,000 ft). Area calculations from the gravity model for salt (Figure 7-1) indicate that the dome encompasses 1,127, 1,090, and 1,057 hectares (2,785, 2,694, and 2,613 acres) at -610, -762, and -914 meters (-2,000, -2,500, and -3,000 ft) MSL, respectively.

Caprock is present over the top of the dome at depths ranging from 217 to 637 meters (713 to 2,090 ft) below the surface (Figures 7-2, 7-3, and 7-4) [elevations -109 to -501 meters (-357 to -1,645 ft) MSL]. TOG-1 cut through 137 meters (450 ft) of caprock. Two wells drilled over the dome, McBee No. 1 Sherman (LETCo 021-3) and McBee No. 1-A Campbell (LETCo 015-1) (Figure 7-1), encountered 255 and 232 meters (837 and 760 ft) of caprock, respectively. The difference in caprock thicknesses observed in TOG-1, 021-3 and 015-1 is probably caused by local irregularities not recognized in the gravity data. The gravity model shows that the caprock gradually decreases in thickness towards the flanks to a minimum of 6 meters (20 ft).

The top of the caprock (TOG-1) is at 217 meters (713 ft) below the surface, and the top of the salt is at 354 meters (1,163 ft). Caprock lithology has been described, and rock samples have been analyzed through microscopic observation and X-ray analysis. It is divided into a lower anhydrite section, a narrow transition zone, and an upper calcite section.

The anhydrite section consists of a mosaic of interlocking crystals 0.1 to 1.0 mm (0.003 to 0.039 in) long. Horizontal

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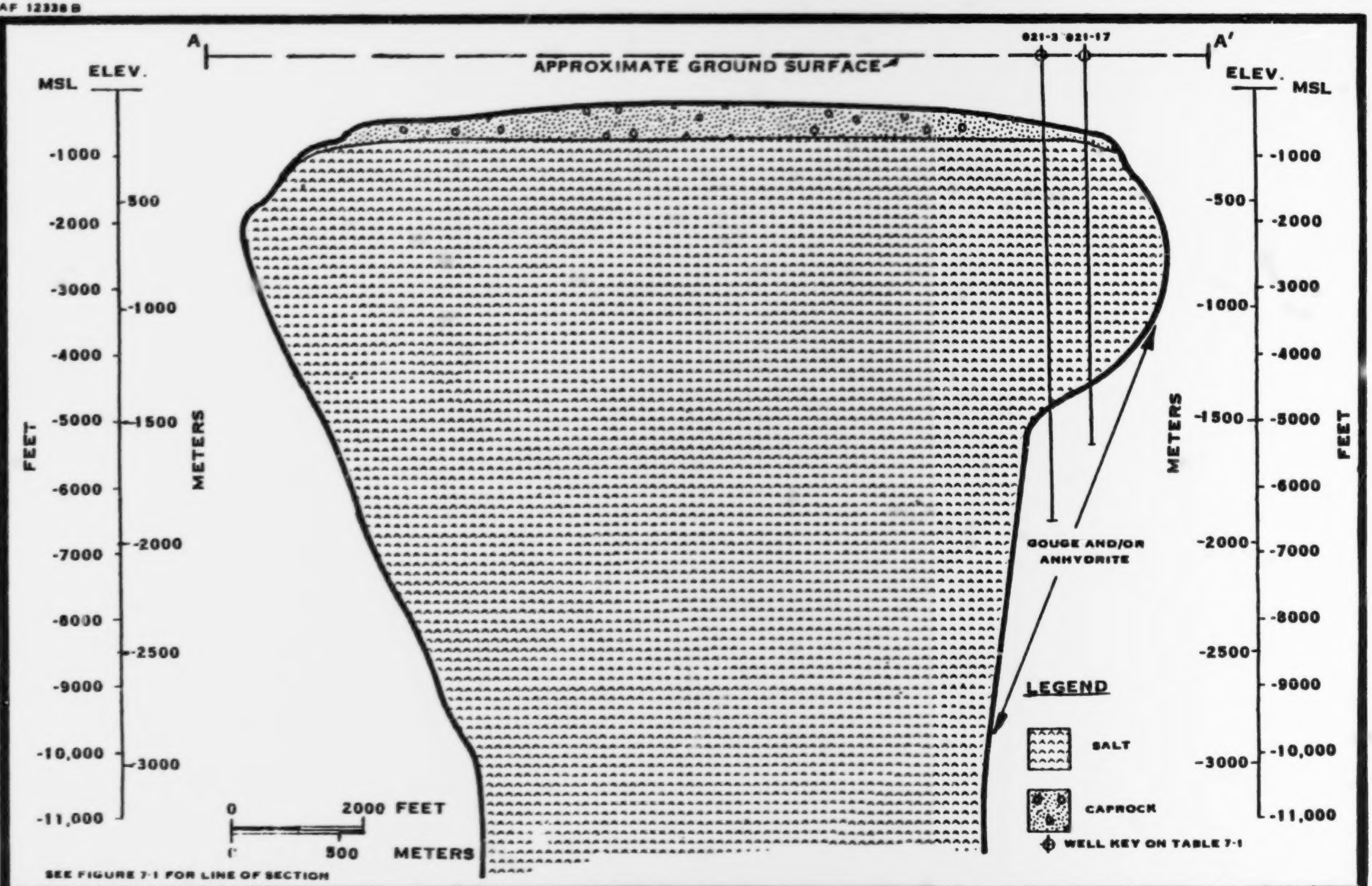
A
A'
APPROXIMATE GROUND SURFACE
021-3
021-17
MSL
ELEV.
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
500
-1000
-1500
-2000
-2500
-3000
FEET
METERS
GOUGE AND/OR ANHYDRITE
LEGEND
SALT
CAPROCK
WELL KEY ON TABLE 7-1
0
2000 FEET
0
500
METERS

SEE FIGURE 7-1 FOR LINE OF SECTION

PREPARED		DATE	8/15/80
REVISED		DATE	[illegible]
REVISED		DATE	
APPROVED		DATE	8/15/80

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GEOLOGIC EVALUATION GULF COAST SALT DOMES

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MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
OAKWOOD DOME
CROSS-SECTION A - A'

JOB NO MV9600

FIGURE 7-2

FIGURE 7-2

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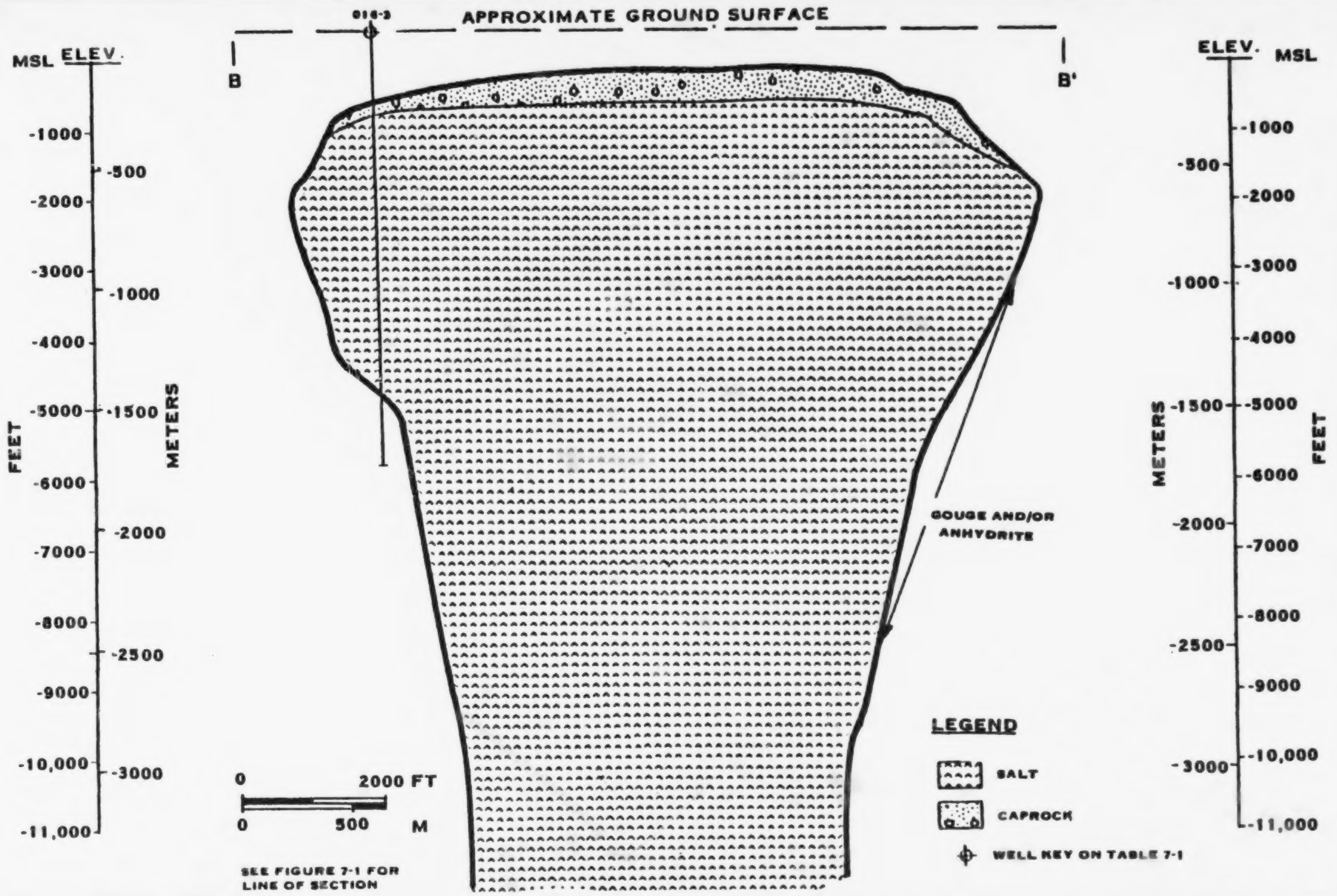
016-3
APPROXIMATE GROUND SURFACE
B
B'
MSL ELEV.
ELEV. MSL
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-500
-1000
-1500
-2000
-2500
-3000
FEET
METERS
GOUGE AND/OR ANHYDRITE
0
2000 FT
0
500
M
LEGEND
SALT
CAPROCK
WELL KEY ON TABLE 7-1

SEE FIGURE 7-1 FOR LINE OF SECTION

FIGURE 7-3

PREPARED tH DATE 8/15/80
REVISED DATE
REVISED DATE
APPROVED DATE /80
T-1106-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
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LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
OAKWOOD DOME AREA
CROSS-SECTION B-B'

JOB NO. MV9600 FIGURE 7-3

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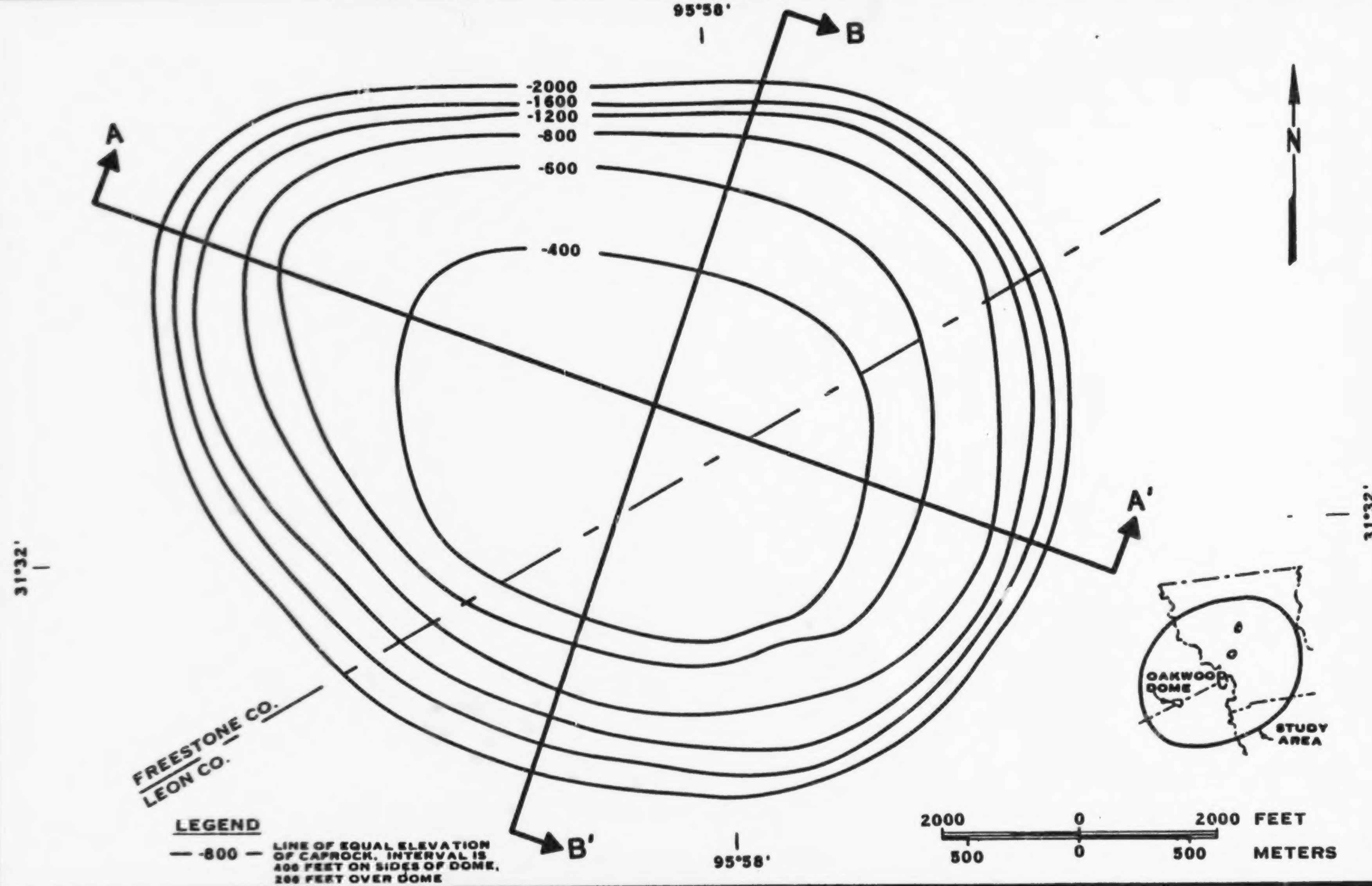
95°58'
B
A
-2000
-1600
-1200
-800
-600
-400
N
A'
31°32'
31°32'
OAKWOOD DOME
STUDY AREA
FREESTONE CO.
LEON CO.
B'
95°58'
2000 0 2000 FEET
500 0 500 METERS

LEGEND

— -800 — LINE OF EQUAL ELEVATION OF CAPROCK. INTERVAL IS 400 FEET ON SIDES OF DOME, 200 FEET OVER DOME

PREPARED ________ DATE 8/15/80
REVISED ________ DATE 11/11/81
REVISED ________ DATE ________
APPROVED ________ DATE 8/15/80

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LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
OAKWOOD DOME
CAPROCK STRUCTURE MAP

JOB NO. MV9600

FIGURE 7-4

FIGURE 7-4

layering is defined by fine-grain [0.015 to 0.004 mm (0.0005 to 0.0001 in)] anhydrite within this section. Dolomite rhombs, which are probably residual from the salt stock, are also present throughout the anhydrite section (Kreitler, 1980). The transition zone is encountered between 275 and 276 meters (902 and 907 ft) below the surface. It consists of an open network of fine-grain calcite, pyrite, and sulfur. Where anhydrite remains, it is commonly surrounded by calcite or gypsum. The gypsum either surrounds the anhydrite grains, or it occurs as fibrous patches associated with fine-grain calcite.

The lower part of the calcite section of the caprock consists of a brecciated, dark gray, fine-grain calcite separated by coarse-grain, secondary calcite. Above 269 meters (881 ft) the fine and coarse calcite grains alternate in continuous horizontal bands. Pyrite, sulfur, dolomite, and quartz rosettes occur in the fine-grain calcite layers. Celestite and dolomite crystals occur within the coarse-grain calcite layers.

The contacts between the caprock and the underlying salt, and the caprock and the overlying Wilcox sandstone are sharp.

It is possible that the two caprock sections described may not be present over the entire dome (Kreitler, 1980). However, 57 meters (186 ft) of sandstones, shales, and limestones were drilled before encountering the salt. No anhydrite was logged in the Texaco No. 3 Keechi (LETCo 021-5) well before encountering salt at 347 meters (1,140 ft).

Below the salt overhang approximately 30 to 61 meters (100 to 200 ft) of material, composed of anhydrite, limestone, shale, and sand, was encountered in boreholes drilled through the overhang at Oakwood Dome. Hardin (1960) states that this zone extends downward along the flanks of the salt pillar and he describes it as an anhydrite sheath and lime gouge. This gouge material can be divided into two distinct zones on the basis of well data and core descriptions: an anhydrite zone and a lime-gouge zone. Both "dead" and "live" oil, as well as hydrogen sulfide, are sometimes associated with both zones.

Adjacent to the salt there is a bluish-gray, dense to hard anhydrite that changes laterally to a white, powdery, brecciated, crystalline and sucrose anhydrite. Chalk and limestone are sometimes reported within the anhydrite, as is a subzone of porous broken dolomite. The zone varies in thickness from approximately 9 to 18 meters (30 to 60 ft).

Underlying the anhydrite zone is the lime gouge zone consisting of a gray, hard to dense, brecciated, crystalline limestone with widely scattered vugs and occasional fractures. The limestone sometimes exhibits a flow structure in this zone. Limey salt and sand with dolomite, anhydrite, and pyrite are reported in association with the lime gouge zone, which varies from 8 to >61 meters (25 to >200 ft) in thickness.

The lime gouge zone generally increases in thickness with depth, down the flank of the salt dome. The anhydrite zone is believed to extend up and over the salt overhang, continuous with the anhydrite caprock previously described. The McBee No. 1 Marie Storms (LETCo 022-3) well (Figure 7-1) on the west side of the dome encountered both zones approximately 1,128 meters (3,700 ft) below the surface. In other wells both zones were encountered at 1,524 to 2,438 meters (5,000 to 8,000 ft) below the surface.

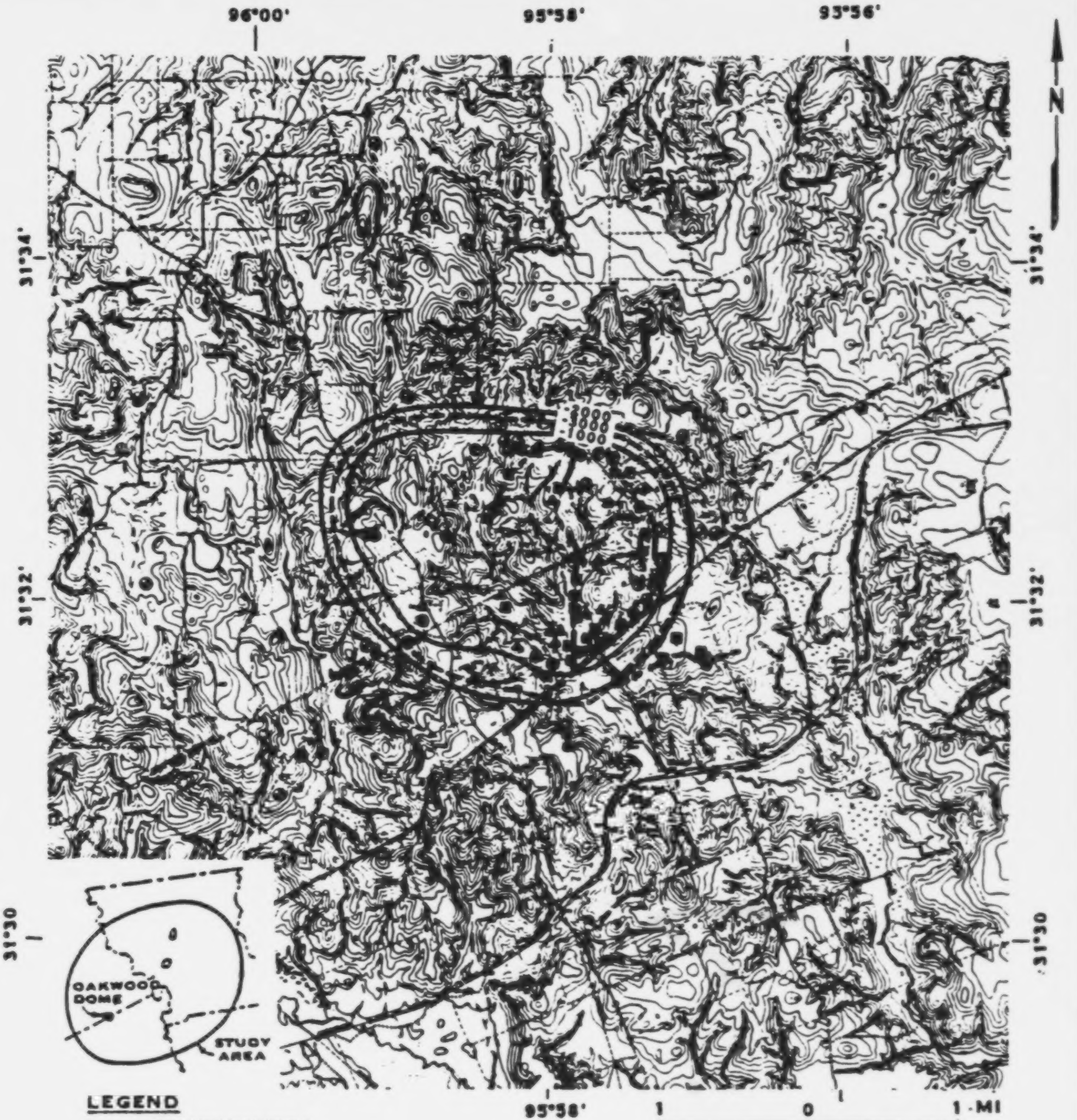
The top of the salt at Oakwood Dome occurs at depths from 310 to 655 meters (1,016 to 2,150 ft) below the surface [-184 to -520 meters (-604 to -1,705 ft) MSL]. Salt core data from TOG-1 indicate the salt to be 90 to 95 percent pure halite, with anhydrite and traces of calcite as impurities. The halite crystals are elongate and are 25 to 76 mm (1 to 3 in) in length. The anhydrite occurs in stringers and no evidence of shear zones within the salt core has been noted.

There has been extensive drilling for oil and gas in the area around the dome. Of the 36 wells on Oakwood Dome that penetrated the caprock, 35 wells drilled into salt (Table 7-1). From the sites of these 35 deep wells in salt, 34 wells were side-tracked so that a total of 77 holes actually extend into the sedimentary section below the overhang.

7.1.2 NEAR-DOME GEOLOGY: This section includes the preliminary work completed in studying the surface and subsurface geology in the vicinity of Oakwood Dome.

7.1.2.1 Surface Geology: The following paragraphs describe the physiographic characteristics, outcrop patterns, and structural features observed at the surface above Oakwood Dome.

7.1.2.1.1 Physiography - The site of Oakwood Dome (Figure 7-5) lies within a region of relatively high elevations, bordered on



LEGEND

⊕	OIL AND GAS WELL
○	LAW ENGINEERING HYDROLOGIC BORING
◎	LAW ENGINEERING SALT CORE BORING
▲	LAW ENGINEERING SHALLOW BORING
—·1000—	LINE OF EQUAL ELEVATION OF SALT. DASHED WHERE BENEATH OVERHANG. INTERVAL IS 1000 FEET.
— —— —	GROUND LEVEL RESISTIVITY HORIZONTAL PROFILE
■	GROUND LEVEL RESISTIVITY VERTICAL SOUNDING

1 0 1 MI

1 0 1 KM

CONTOUR INTERVAL IS 20 FEET, DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY 1: 24,000 QUADRANGLE.

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T-1469-1

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EAST TEXAS STUDY AREA
OAKWOOD DOME AREA
TOPOGRAPHIC MAP AND DATA UTILIZED IN ANALYSIS
JOB NO MV9600 FIGURE 7-5

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the north and east by Upper Keechi Creek and on the south by Buffalo Creek, both of which drain south and east into the Trinity River. Elevations vary from 76 meters (250 ft) along the creeks to about 168 meters (550 ft) near the center of the dome area. Local relief ranges from about 15 to 46 meters (50 to 150 ft). The central part of the high region consists of an irregular ridge of rounded, elongate hills oriented roughly west-northwest to east-southeast. This ridge was probably formed by erosion of sandy beds surrounding an elongate outcrop of more resistant claystone and ironstone. Such litho-structural control of topographic expression is pronounced through the Oakwood Dome area because of the variable resistance of the outcropping units.

An arcuate ring of hills roughly outlines the surface projection of the dome [-610-meter (-2,000-ft)-MSL contour] (Figure 7-5). Within the ring of hills is a central depression, with elevations as low as 91 meters (300 ft), where the high ridge is breached on the southeast side of the dome area. Other low areas, some below 91 meters (300 ft) in elevation, occur along the outer perimeter of the arcuate ridge. The ring of hills apparently results from preservation of a unit relatively resistant to erosion. The circular pattern of these outcrops reflects the dip of beds away from the dome center, presumably in response to domal uplift.

The Oakwood Dome area is drained principally by a dendritic network (Figure 7-6). The drainage gathers southeasterly into Alligator Creek, passing through a breach in the encircling ring of low hills which forms the basin's drainage divide. Channels

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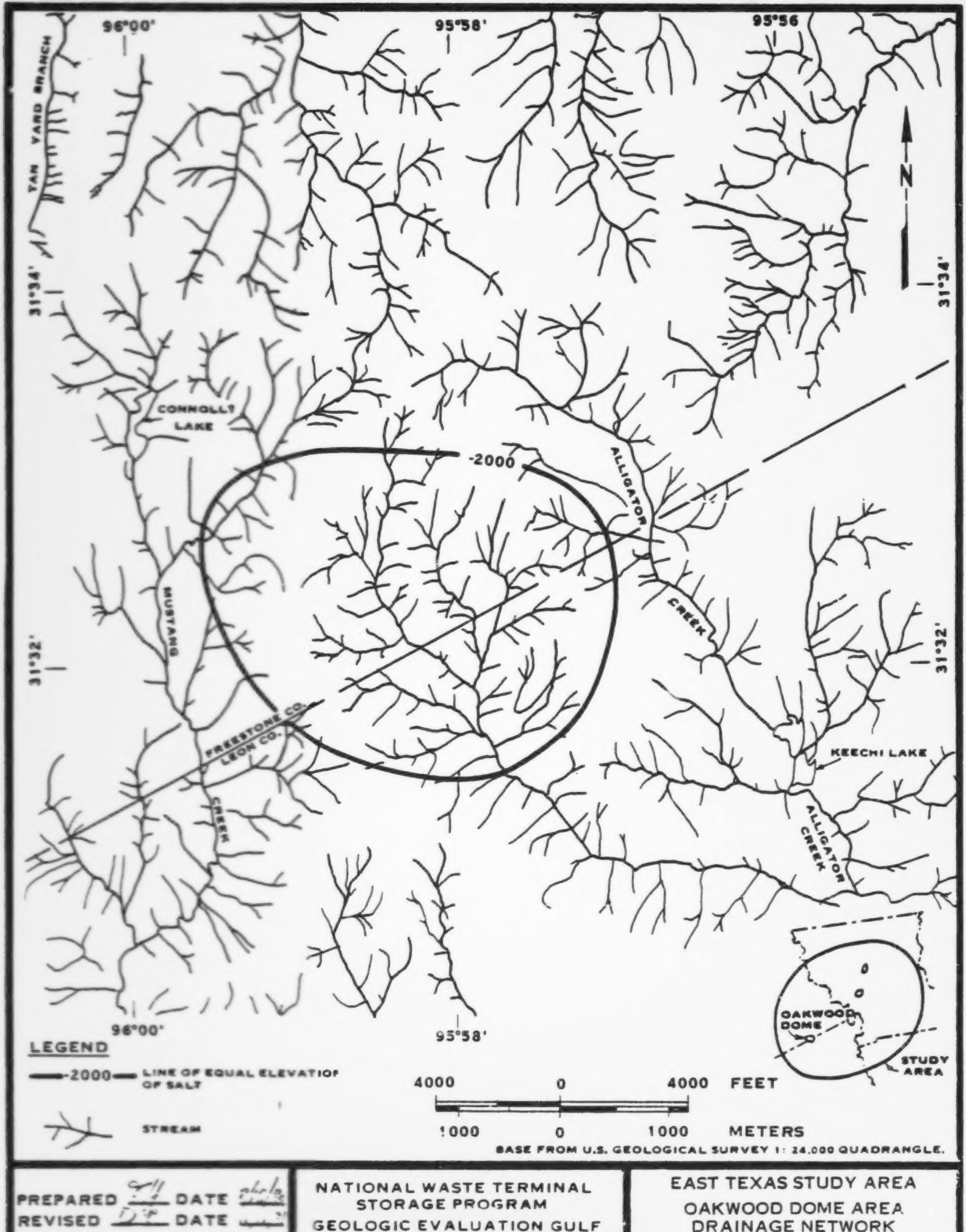
96°00'
95°58'
95°56
TAN YARD BRANCH
N
31°34'
31°34'
CONNOLLY LAKE
-2000
ALLIGATOR CREEK
MUSTANG CREEK
31°32'
31°32'
FREESTONE CO.
LEON CO.
KEECHI LAKE
ALLIGATOR CREEK
OAKWOOD DOME
STUDY AREA
96°00'
95°58'
LEGEND
-2000 LINE OF EQUAL ELEVATION OF SALT
STREAM
4000 0 4000 FEET
1000 0 1000 METERS
BASE FROM U.S. GEOLOGICAL SURVEY 1: 24,000 QUADRANGLE.

PREPARED ______ DATE ______
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED ______ DATE ______
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MARIETTA GEORGIA

EAST TEXAS STUDY AREA
OAKWOOD DOME AREA
DRAINAGE NETWORK

JOB NO. MV9600 FIGURE 7-6

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115

of third-order or greater within the basin typically flow south to southeast, parallel to channels of equivalent order outside the dome area, apparently following the regional dip. Major channels within the dome area show no anomalous changes in orientation.

Above the dome, drainage density is 6 km (4 mi) per square mile. This anomalously dense drainage has been attributed to the dome's positive topographic expression, and it suggests that drainage overlying Oakwood Dome is immature compared to that overlying other domes in the study area (Kreitler and others, 1980). The drainage system, developed after deposition of the terrace around Oakwood, became incised 3 to 8 meters (10 to 25 ft) below the base of the terraces.

7.1.2.1.2 Outcropping Geologic Units - Within the site area the ages of the outcropping beds range from Tertiary (Eocene) to Quaternary (Pleistocene and Recent) (Figure 7-7). The lithology of the outcropping units is described in Chapter 6.

Northwest of Oakwood, beyond the influence of domal uplift, the exposed geologic units follow a pattern characteristic of outcropping formations along the western portion of the East Texas Basin. The depositional strike, which corresponds to the structural strike at the outcrop, is from southwest to northeast (Figure 6-7), with gentle dips of 1 to 2 degrees toward the southeast.

The Eocene outcrop consists of rocks of the lower to middle Claiborne Group. These deposits, from oldest to youngest, are the Carrizo, Reklaw, and Queen City Formations. The formations of the Claiborne Group at the domal area resemble their correlatives throughout the Northeast Texas Embayment, consisting of alternating marine and nonmarine, argillaceous to arenaceous sequences representing cyclic deposition. The Quaternary (Pleistocene and Recent) deposits within the domal area consist of alluvial terrace sediments and alluvium.

The Carrizo Formation is exposed only within two small areas directly over Oakwood Dome (Figure 7-7) and it is approximately 34 to 40 meters (110 to 130 ft) thick. Subsurface data from the DOE Settlemyre TOH-2A (see Figure 7-1 and Appendix) well indicate that the Carrizo dips away from the dome at an angle of less than 10 degrees. Well data show thinning of Carrizo sediments in an arcuate trending band, from the southwest over the dome to the southeast. The Carrizo is exposed extensively 8 km (5 mi) northwest of the dome (Kreitler and others, 1980).

The Reklaw is exposed within the northern half of the dome area (Figure 7-7), and the formation represents pro-delta, open-marine deposition. The Reklaw conformably overlies the Carizzo Formation and dips 10 to 20 degrees away from the dome. The thickness of the Reklaw varies from 30 to 46 meters (100 to 150 ft), according to shallow boring data.

The Queen City is the dominant formation exposed around Oakwood Dome. This formation represents deposition in a deltaic to shallow marine shelf environment within the domal area. Over the dome, the upper portion of the Queen City Formation is missing. The sands and clays of the middle and lower portion of the Queen

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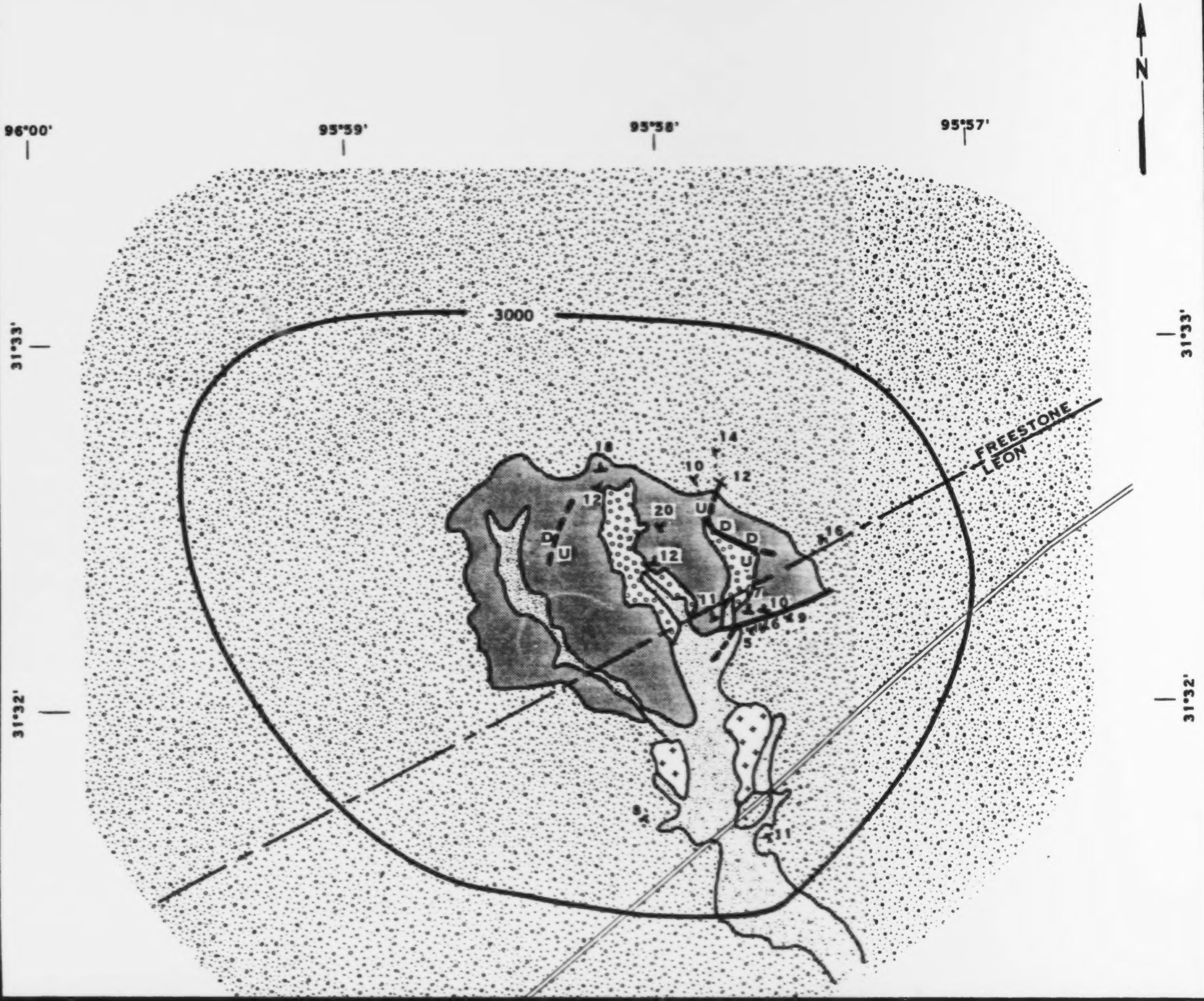
N
96°00'
95°59'
95°58'
95°57'
31°33'
31°32'
31°33'
31°32'
-3000
FREESTONE
LEON
18
14
10
12
12
20
U
D
D
U
D
U
12
16
11
7
10
6
9
5
8
11

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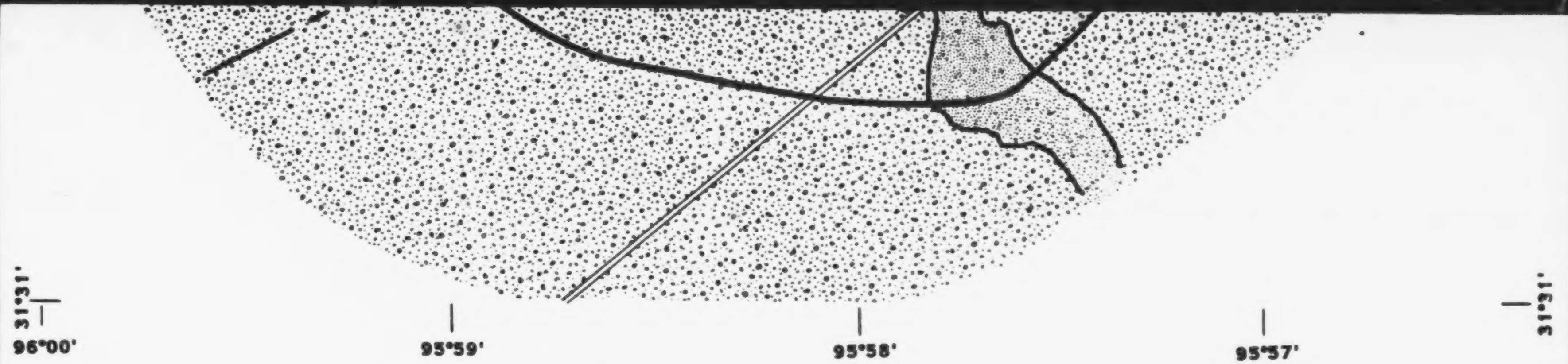
31°31'
96°00'
95°59'
95°58'
95°57'
31°31'

LEGEND

PLEISTOCENE AND RECENT		▨	ALLUVIUM
		▨	TERRACE
EOCENE	CLAIBORNE	▨	QUEEN CITY FORMATION
		▨	REKLAW FORMATION
		▨	CARRIZO FORMATION
		—	FORMATION CONTACT
		U/D	FAULT-UPTHROWN/DOWNTHROWN
		— — —	FAULT, DASHED WHERE INFERRED
		⊥50	STRIKE AND DIP (DIRECTION AND AMOUNT)
		-3000-	LINE OF EQUAL ELEVATION OF SALT
		//	ROAD OR HIGHWAY

OAKWOOD DOME
STUDY AREA

2000
0
2000 FEET
500
0
500
METERS

GEOLOGY FROM TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

PREPARED SK DATE
REVISED DATE
REVISED DATE
APPROVED DEP DATE 11/17/81

T-1111-3

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
OAKWOOD DOME AREA
GEOLOGIC MAP

JOB NO. MV9600

FIGURE 7-7

City Formation are exposed over most of the dome area (Figure 7-7). The thickness of the formation approaches 98 meters (320 ft), but it is generally thicker on the flanks of the dome. The Reklaw is conformable and gradational upward to the overlying Queen City Formation. Dips as high as 19 degrees away from the dome have been measured in the Queen City exposure around the periphery of the dome.

Quaternary terrace deposits on Oakwood Dome cover a small area on either side of a tributary of Alligator Creek (Figures 7-6 and 7-7). The terraces consist of approximately 3 meters (10 ft) of sandy clay to medium sand, containing a few pebbles of metamorphic rock. The pebbles of metamorphic rock suggest that these terraces were deposited by a large stream connected to the regional drainage system (i.e., Trinity River), which originated further inland.

Recent alluvium is present along portions of most of the creeks in the area. These deposits are confined generally to elevations below 104 meters (340 ft) within the depression overlying the dome, and to elevations below 91 meters (300 ft) south of the dome. The thickness of the alluvium approaches 6 meters (20 ft) in some places and thins away from the creeks. Shallow boring data show a general thickening of alluvial sediments over the dome. This thickness reaches 11 meters (36 ft) in the drainage course over the central topographic depression. Approximately 305 meters (1,000 ft) north of the central depression no alluvium is present in the stream channel. On the south edge of the dome only 3 meters (10 ft) of Recent alluvium is present according to electrical resistivity interpretation.

[redacted]

7.1.2.1.3 Structure - Sediments overlying and surrounding the salt mass of Oakwood Dome have been lifted and tilted by the upward movement of the salt. Uplift is indicated by several distinctive surface geologic features:

(1) Carrizo and Reklaw inliers within the Queen City over the dome (Figure 7-7)

(2) Dips away from the dome at angles of up to 20 degrees

(3) Faults upthrown towards the dome center

(4) Radial pattern of normal faults.

The surface faults appear to die out laterally before reaching the peripheral outline of the salt mass. Displacement, where evident in surface exposures, is commonly less than 3 meters (10 ft). A major fault (Figure 7-7), trending east-northeastward with a displacement of more than 46 meters (150 ft), is located on the east side of the dome. Subsurface evidence indicates that this fault, largely obscured at the surface by alluvium, has moved the upper Carrizo Formation on the north side of the fault up against the lower portion of the Queen City Formation on the south side. The fault plane dips 50 to 80 degrees to the south.

Some lineaments mapped from remote sensing data correspond to topographic elements (Figure 7-8). It is possible that the intricate system of lineaments radiating generally away from the center of the dome is indicative of some minor faulting. Some lineaments are commonly represented by deeply eroded, high-walled gullies with relief up to 9 meters (30 ft).

7.1.2.2 Subsurface Geology: The subsurface geologic section around Oakwood Dome is composed of beds of the Upper Triassic

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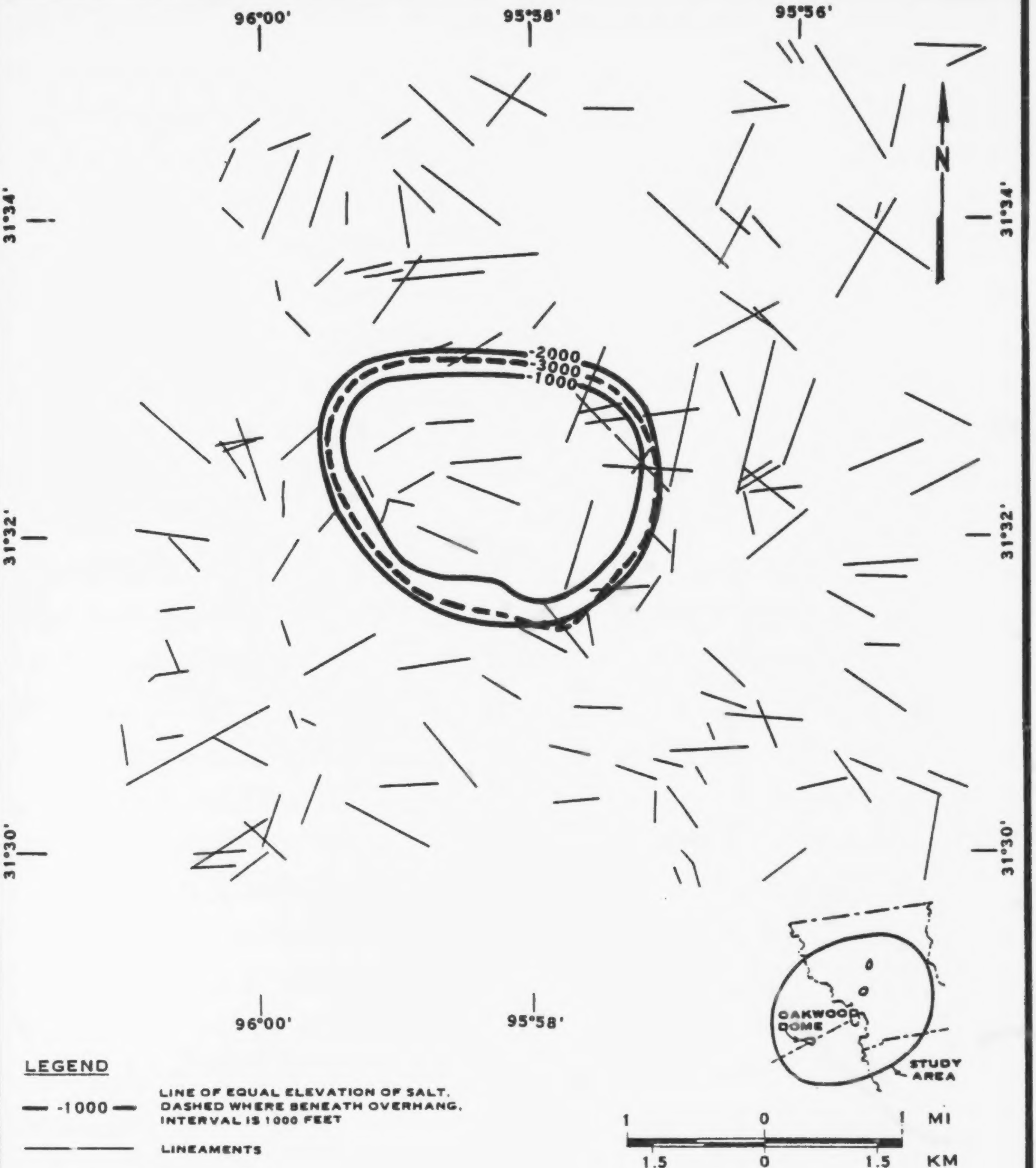
96°00'
95°58'
95°56'
31°34'
31°32'
31°30'
N
-2000
-3000
-1000
OAKWOOD DOME
STUDY AREA
LEGEND
-1000
LINE OF EQUAL ELEVATION OF SALT, DASHED WHERE BENEATH OVERHANG, INTERVAL IS 1000 FEET
LINEAMENTS
1
0
1
MI
1.5
0
1.5
KM

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980).

PREPARED ______ DATE ______
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED ______ DATE ______
T-1112-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
OAKWOOD DOME
LINEAMENT MAP

JOB NO. MV9600 FIGURE 7-8

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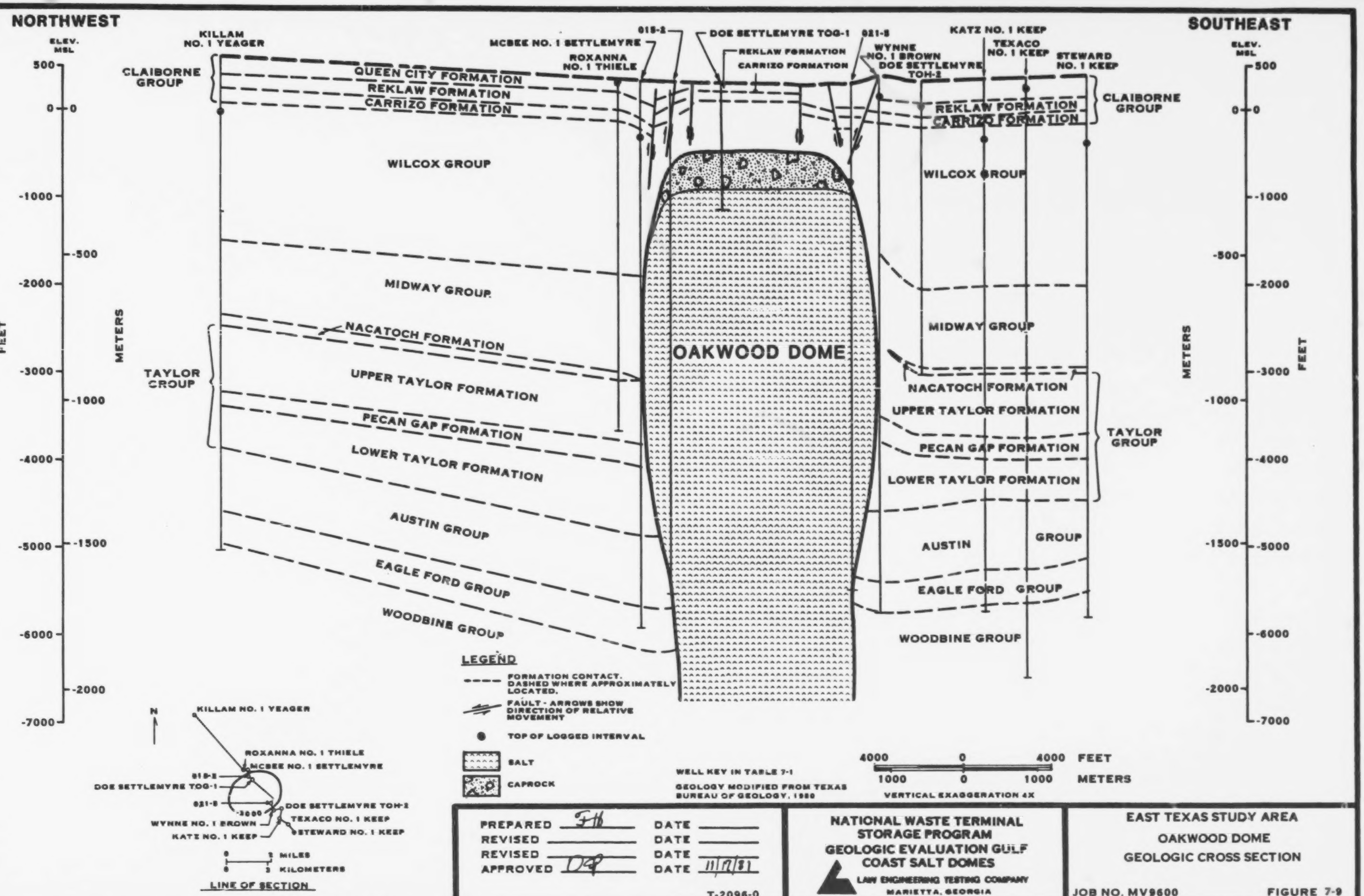
Series, Lower and Upper Jurassic Series, the Comanchean and Gulfian Series, and the Paleocene and Eocene Series (Table 6-1).

Progressive domal growth and uplift has caused steep dips in some beds near the dome so that an accurate determination of thickness is not feasible. Preliminary structural mapping of Upper Cretaceous and Tertiary horizons within an 8-km (5-mi) radius of Oakwood Dome (BEG, 1980) indicates the southeasterly regional structural dip is locally modified at Oakwood Dome. At the periphery of the mapped area, regional trends are influenced by the positive structures of Red Lake Oil Field to the northwest and Buffalo Oil Field to the south. At the Red Lake Oil Field, a southward steepening of the general regional structure is apparent south of Oakwood Dome. The Buffalo Field structure locally interrupts the regional southwestward dip.

Well logs and preliminary isochore maps (BEG, 1980) in the vicinity of the dome were used to infer subsurface lithology and thickness of units in the domal area. A northwest-southeast stratigraphic cross section illustrates the geologic setting of the Upper Cretaceous and Tertiary formations (Figure 7-9). No wells in the vicinity of the dome have penetrated units older than the Smackover Formation of the Upper Jurassic (Figure 6-22). Although the lithology of units below the Smackover Formation, in the vicinity of Oakwood Dome, is not known, seismic data provide a basis for estimating thicknesses. The lithology and thicknesses of the deeper units near Oakwood Dome probably do not differ significantly throughout the study area. These properties are described in Section 6.2.2 of this report and they are


NORTHWEST
SOUTHEAST
ELEV. MSL
FEET
METERS
500
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-500
-1000
-1500
-2000
KILLAM NO. 1 YEAGER
ROXANNA NO. 1 THIELE
MCBEE NO. 1 SETTLEMYRE
015-2
DOE SETTLEMYRE TOG-1
REKLAW FORMATION
CARRIZO FORMATION
021-5
WYNNE NO. 1 BROWN
DOE SETTLEMYRE TOH-2
KATZ NO. 1 KEEP
TEXACO NO. 1 KEEP
STEWARD NO. 1 KEEP
CLAIBORNE GROUP
QUEEN CITY FORMATION
REKLAW FORMATION
CARRIZO FORMATION
WILCOX GROUP
MIDWAY GROUP
NACATOCH FORMATION
TAYLOR GROUP
UPPER TAYLOR FORMATION
PECAN GAP FORMATION
LOWER TAYLOR FORMATION
AUSTIN GROUP
EAGLE FORD GROUP
WOODBINE GROUP
OAKWOOD DOME
AUSTIN
GROUP
EAGLE FORD
GROUP
LEGEND
FORMATION CONTACT. DASHED WHERE APPROXIMATELY LOCATED.
FAULT - ARROWS SHOW DIRECTION OF RELATIVE MOVEMENT
TOP OF LOGGED INTERVAL
SALT
CAPROCK
N
-3000
0 2 MILES
0 3 KILOMETERS
LINE OF SECTION
4000 0 4000 FEET
1000 0 1000 METERS
VERTICAL EXAGGERATION 4X

WELL KEY IN TABLE 7-1

GEOLOGY MODIFIED FROM TEXAS BUREAU OF GEOLOGY, 1980

PREPARED	Fh	DATE	
REVISED		DATE	
REVISED		DATE	
APPROVED	DP	DATE	11/17/81

T-2096-0

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
OAKWOOD DOME
GEOLOGIC CROSS SECTION

JOB NO. MV9600

FIGURE 7-9

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summarized in Table 6-1. The following section describes the geometry of subsurface units not exposed at the surface of Oakwood Dome.

7.1.2.2.1 Upper Jurassic - The Upper Jurassic Series in the domal area is represented by the Louark and Cotton Valley Groups. The Louark Group is only partially represented by the Smackover, Buckner, and Gilmer Formations. The Skelly No. 1 Gehrels (LETCo 43-3) well (Figure 6-22) penetrated the Smackover but was not drilled through the entire formation. The thickness of the Smackover represented in this well is 180 meters (590 ft). The thicknesses of the Buckner and Gilmer Formations, as presented in Well 43-3, are 140 and 210 meters (460 and 690 ft), respectively. The Cotton Valley Group consists of the Bossier, Schuler, and Knowles Formations. In the McCormick No. 1 Recknor (LETCo 53-4) well (Figure 6-22), the thickness of the Bossier is 448 meters (1,470 ft). The Schuler Formation thickens into the rim syncline adjacent to the dome on the northwestern flanks, and it thins farther northwestward (Figure 6-22). On the southeast flank of the dome, the Schuler thins adjacent to the dome but thickens farther to the southeast (Figure 6-22).

7.1.2.2.2 Lower Cretaceous - The Lower Cretaceous is composed of the Comanchean Series, which consists of the Trinity, Fredericksburg, and Washita Groups.

Well 53-4 drilled through the Travis Peak Formation, within the Trinity Group, approximately 1.6 km (1 mi) south of the dome

(Figure 6-22). Here, the beds of the Trinity Group are dipping at very low angles. The Pettet Formation consists of 94 meters (310 ft) of interbedded limestones and shales. The entire lower Glen Rose Formation has an apparent thickness of 212 meters (695 ft), grading upward into the 130-meter (425-ft)-thick Ferry Lake Formation. The Upper Glen Rose Formation is 287 meters (940 ft) thick. The Paluxy Formation is 82 meters (270 ft) thick in Well 53-4.

The Fredericksburg Group consists of the Goodland and Kiamichi Formations. The Goodland Formation comprises three massive limestone beds, and the Kiamichi Formation consists of shale interbedded with thin limestone stringers. The thickness of the Fredericksburg Group is 14 meters (45 ft) in Well 015-1, compared with 113 meters (370 ft) in Well 53-4, farther from the dome. The dip of the beds (approaching 11 degrees, according to the dip log) does not account for an apparent overthickening of units in Well 53-4. Therefore, it appears likely that contemporaneous deposition filled the rim syncline which was developing as salt was drawn into the dome.

The Washita Group consists (from bottom to top) of the Duck Creek Limestone; the Duck Creek Shale; and the Fort Worth, Denton, Weno-PawPaw, Main Street, Grayson, Buda, and Maness Formations. The sequence of units comprising the Washita Group is characterized by alternating layers of dense limestone and fissile shale. In Well 015-1, which is adjacent to the dome, dips of 6 to 11 degrees were recorded. The total thickness of the group is 271 meters (890 ft).

7.1.2.2.3 Upper Cretaceous - The Upper Cretaceous is represented by the Gulfian Series consisting of the Woodbine, Eagle Ford, Austin, Taylor, and Navarro Groups.

Formations of the Woodbine Group cannot be differentiated within the dome area. The thickness of the Woodbine is approximately 244 meters (800 ft); however, in Well 53-4, the measured thickness is 181 meters (595 ft). Because no faulting has been observed in Well 53-4, thinning could be caused by depositional influences. In Figure 7-9 the Woodbine is upturned against the north side of Oakwood. The upturning of beds adjacent to the dome is indicative of dome growth development. In other wells around the perimeter of the dome, dips up to 60 degrees have been reported in the Woodbine. The base of the Woodbine is placed at the lowermost sandstone.

The Eagle Ford is mapped as a group at the surface, though it sometimes ranks as a formation in the subsurface, illustrating the typical development of stratigraphic complexities downdip into a basin. The uppermost sandstone is the Sub-Clarksville Sand. The thickness of the Eagle Ford Group ranges from 98 meters (320 ft) in Well 53-4, to 125 meters (410 ft) in the Wynne No. 1 Brown (LETCo 44-2) well, which is 0.40 km (0.25 mi) closer to the dome. Data from nearby wells show the Eagle Ford thickening towards the dome, but stratigraphic relationships adjacent to the dome are not clear.

The Austin Group is divided into the Ector, the Middle Austin, and the Gober Formations. The thickness of the Group in Well 53-4 is 218 meters (715 ft); it is 311 meters (1,020 ft) in

Well 44-2. The beds of the Austin Group are upturned adjacent to the dome on the north side (Figure 7-9). The units of the group generally thicken southwest and northeast of the dome corresponding to areas of rim synclinal development (Figures 6-15 and 6-29).

The Taylor Group is divided into three formations: the Lower Taylor, Pecan Gap Chalk, and the Upper Taylor. Observations in nearby wells and isochore mapping (Figure 6-15) show that the beds of the Lower Taylor thicken toward the dome. The sediments of the Pecan Gap Formation, as indicated by well data, thicken toward the east in the domal area, and they also show an area of thick deposition about 1.6 km (1 mi) southwest of the dome. This area corresponds to rim synclines on the southwest and less distinct rim synclines to the northeast, as indicated by structural contour maps (i.e., Figure 6-30). The thickening of sediments into the rim syncline is the result of lateral movement of salt into Oakwood Dome. Thickening of the Taylor Group sediments and upturning of the beds occur directly at the dome. In Well 53-4, all three units are present, and the total thickness of the group is 241 meters (790 ft). In Well 44-2 the thickness is 329 meters (1,080 ft).

The Navarro Group is subdivided into the Lower Navarro, Nacatoch, and Upper Navarro Formations. Wells in the vicinity of the dome indicate thinning of the Nacatoch Sand toward the dome and a general trend of sediment thickening to the west and north of the domal area. The approximate thickness of the Navarro Group at the dome is 247 meters (810 ft) (Well 53-4).

7.1.2.2.4 Tertiary System - The Tertiary System includes the Paleocene and Eocene Series consisting of, in ascending order, the Midway, Wilcox, and Claiborne Groups.

The lithology of the Midway Group is described in Section 6.2.2.4.1. In the TOH-2A well, thickness of the group is 198 meters (650 ft), with dips of less than 8 degrees toward the southeast. Farther away from the dome, in Well 53-4, the apparent thickness is 204 meters (670 ft). However, the Midway shows no significant thinning of beds toward the dome but a slight thickening of beds westward from the dome, as indicated by seismic data (Figure 6-22).

The Wilcox Group* in the vicinity of the dome has been subdivided into four units by BEG. On the basis of interpretation, it has a lower "shale" zone approximately 98 meters (320 ft) thick, overlain by an approximately 222-meter (730-ft)-thick sandy zone, which is below a less sandy zone approximately 128 meters (420 ft) thick, and an uppermost sandy zone approximately 107 meters (350 ft) thick. In the TOH-2A well, the lower 457 meters (1,500 ft) of the Wilcox Group described above consists of alternating layers of silt and sand with some layers of fissile claystone (soft shale); above this unit is a massive sand, 61 meters (200 ft) thick. Above the sand is a medium-gray siltstone zone, 107 meters (350 ft) thick. Also, thin beds of lignite were found throughout the Wilcox. The thickness of the Wilcox Group in this well is 564 meters (1,850 ft). A comparison of TOH-2A on the flank of the dome with TOG-1 directly over the top of the dome shows all four units of the Wilcox are present in TOG-1, but these units are much thinner than those in TOH-2A. The thickness of the Wilcox at TOG-1 is 165 meters (540 ft). Well data depicting the Wilcox units exhibit thinning toward the dome as well as a regional thickening toward the southeast of the domal area (Figure 7-9).

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*The lowermost portion of the Wilcox Group is considered late Paleocene, whereas the rest of the group is early Eocene.

7.1.2.2.5 Faulting - Subsurface and surface mapping studies have recognized radial faulting on the domal flanks and overlying the dome (Kreitler and others, 1980). Off-the-dome faulting, indicated by Geomap within an 8-km (5-mi) radius, is confirmed by interpretation of available seismic data.

Radial faults have been mapped in the subsurface at Oakwood on top of the Woodbine, Lower Navarro, and Wilcox beds, and on the surface in the Claiborne Group. The faults mapped on the various horizons do not appear to be related; however, the mechanism is assumed to be the same. The stresses which activated the faults apparently were initiated by contemporaneous compaction and settling of the flanking sediments. The normal radial faults result from vertical stresses dominant in uplift. At least three normal faults, downthrown away from the dome, have been mapped on the surface (Krietler and others, 1980) in the Claiborne Group. Although a prominent pattern of radial lineaments was noted over the supradomal surface (Figure 7-8), no indications of faulting or warping of the Quaternary terrace deposits were reported.

In addition to faulted beds adjacent to and overlying the dome, structural displacement has been recognized to the east, southeast, and south of the dome from seismic reflection data corresponding to the subsurface extension of the Mt. Enterprise Fault Zone (Figure 6-22). The fault zone is a graben structure which trends generally southwesterly along the southeastern portion of the study area (Figure 6-19). Displacements within the graben increase with depth, affecting Upper and Lower Cretaceous strata with the maximum throw in a range of 152 to 213 meters (500 to 700 ft). A southwesterly trending fault is mapped south of Oakwood Dome and east of the town of Buffalo (Figure 6-19). The range of displacement in this fault downthrown to the south is similar to that observed in the Mt. Enterprise Fault System.

7.1.2.3 Dome Growth: Seismic interpretation in the area of Oakwood Dome suggests a breached salt pillow origin for Oakwood Dome (Figure 6-22). Initiation of pillow development during Late Jurassic is suggested by the thickening of the Smackover sequence northwest of Oakwood Dome and the thinning to the southeast (Figure 6-22). Uneven sediment loading during the Late Jurassic apparently resulted in the thickening of the Gilmer Limestone (Figure 6-22) southeast of Oakwood Dome, suggesting salt migration into Buffalo Dome and thus separating the two salt strucures by a trough.

The extrusion of salt from the dome subsequent to Gilmer deposition is indicated by the thickening of units of the Schuler sequence northwest of Oakwood Dome (Figure 6-22). The thin sequence of Schuler on the southeast flank of Oakwood Dome is indicative of no salt movement into the dome. On the contrary, the thickening of the Schuler sequence farther to the southeast suggests that it is the result of continued flow of salt into the Buffalo structure farther to the south.

Thickening of the Travis Peak sequence toward Oakwood Dome from the southeast and northwest reflects continued salt movement into the dome.

Although salt movement was still occurring during the Cretaceous, Oakwood Dome was itself in the burial stage. The top of the salt remained below the changing sedimentary surface during the deposition of the Taylor and Navarro Groups. Accordingly, Oakwood Dome was moderately high topographically and it had only a slight effect on the overlying depositional sequence. The northwest to southeast cross section (Figure 7-9) through Oakwood Dome also suggests domal growth during the Upper Cretaceous, indicated by a very slight thickening toward the dome and upturning of beds adjacent to its flanks. The restrictions of structural lows and associated areas of thick sediments southwest and northeast of Oakwood suggest a limited salt source (Figure 6-29).

The thinning of the section over the domal area, from lower Taylor through Claiborne time, suggests that domal movement continued through Claiborne deposition. The absence of faulting or warping of the Quaternary terrace deposits indicates that there has been no post-Quaternary uplift. However, BEG reported that alluvial deposits directly over the crest of the dome are thicker than off the flank. This is interpreted by BEG as an indication of possible collapse in the caprock or salt, or retreat of the salt stock.

7.1.3 MINERAL RESOURCES: Petroleum and lignite are the significant mineral resources in the Oakwood domal area (Figure 7-10).

Petroleum exploration and development at Oakwood has been continuous since the discovery of Oakwood Dome Oil Field in 1958. Cumulative oil production for the field, as reported by the Texas Railroad Commission (1979), is 2,115,715 barrels. Production curves plotted for the field indicate a decline in production since 1963, with 1978 annual production for the field totaling 5,609 barrels. The 1978 figure represents production from two wells currently producing at the field, the Hughey No. 1 Coleman (LETCo 021-10) and the Texaco No. 3 Rabe (LETCo 016-17) wells, located on the east flank of the dome.

Production to date at the dome has generally been limited to the eastern half, where wells produce from beneath the salt overhang in the sands of the Woodbine Formation. Reservoir characteristics of the Woodbine at the dome indicate an approximate average porosity of 23 percent and an average API gravity range of 33 to 37 degrees. The average depth to the pay zone in the field is 1,725 meters (5,660 ft). Hydrocarbon entrapment at the dome is complex and varied, including faulting, lenticularity of reservoir units, and truncation of beds at domal flanks.

Future petroleum potential in the near-dome area was evaluated by Murray (1979). The results of Murray's findings indicate

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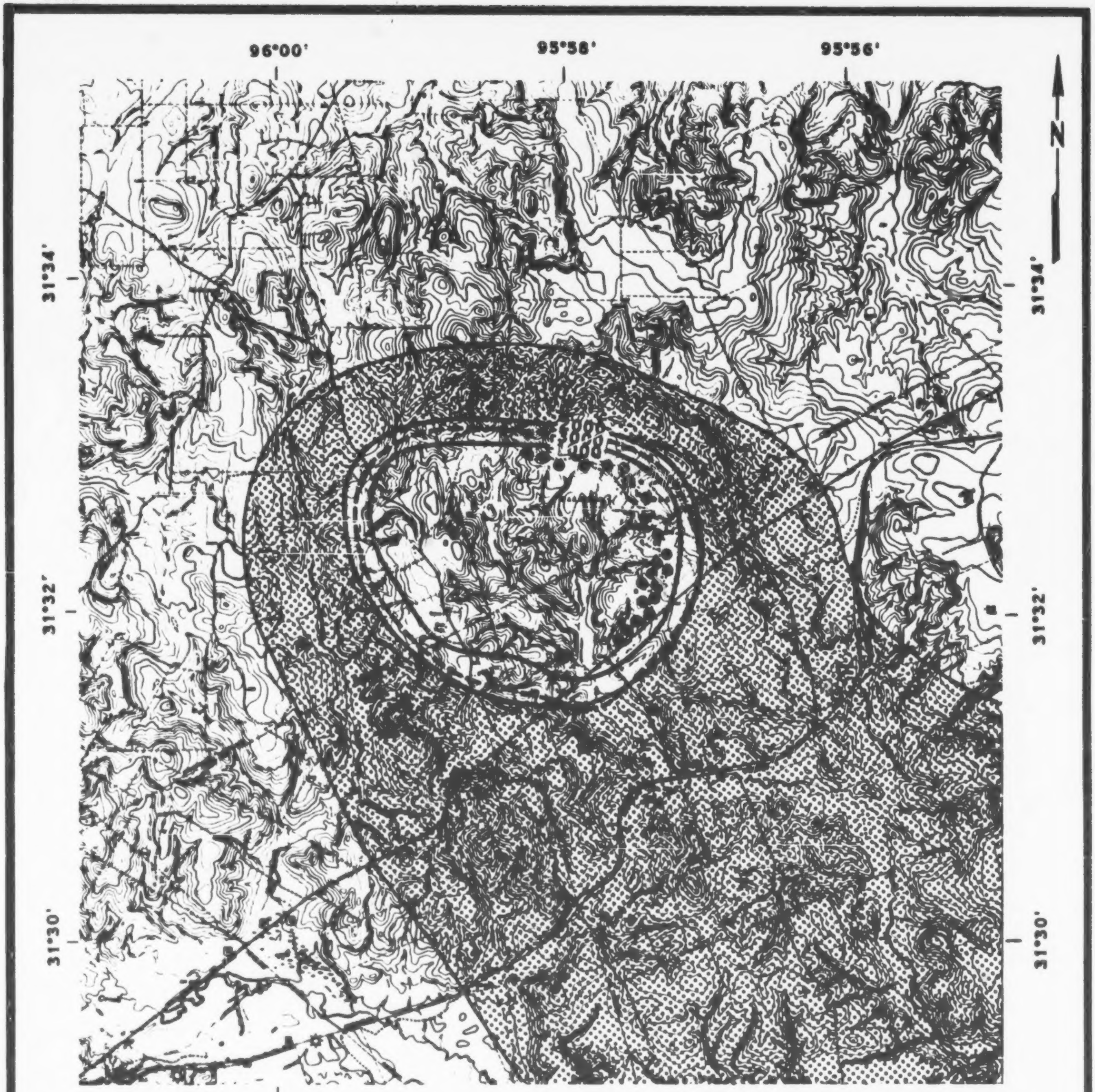
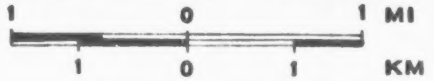
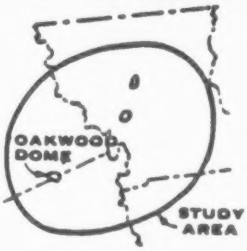




LEGEND

- ● OIL OR GAS PRODUCTION WELLS
- POTENTIAL LIGNITE
- — -2000 — LINE OF EQUAL ELEVATION OF SALT, DASHED WHERE BENEATH OVERHANG, INTERVAL IS 1000 FEET.



CONTOUR INTERVAL 20 FEET.
DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY
1: 24,000 QUADRANGLE.

LOCATION OF POTENTIAL LIGNITE
MODIFIED FROM KAISER (1974).

PREPARED ____ DATE [illegible]
REVISED CP DATE [illegible]
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APPROVED [illegible] DATE [illegible]
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NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

OAKWOOD DOME AREA
MINERAL RESOURCE
DEVELOPMENT

JOB NO. MV9600 FIGURE 7-10

BEST DOCUMENT AVAILABLE

numerous Upper Jurassic and Lower Cretaceous horizons with good prospectivity in the East Texas area, including the Upper Jurassic Cotton Valley Group and the Lower Cretaceous Travis Peak, Pettet, and other Trinity Group sandstones. However, potentials at near-dome localities were quite low; for example, at Oakwood Dome the future potential was rated poor to fair.

Deep-basin lignites of the Upper Wilcox Group, widely distributed throughout the study area, may have an important future resource potential. At Oakwood Dome, as at other salt dome locations, the resource potential of the deep-basin lignites was enhanced by salt intrusion and related structural doming that brought the deep-basin lignites closer to the surface and thereby reduced initial development costs. Large thicknesses of lignite have been reported in the McBee No. 4 Settlemyre (LETCo 016-16) and Holt-Young No. 1 Chambers (LETCo 44-7) wells at the dome; however, to date, field borings have neither supported or disclaimed the reports. Future development at the site of the dome depends on the substantiation of a minimum commercial thickness of lignite or the development of production-type gasification systems.

Although numerous other mineral resources are noted by Murray (1979) to be present at Oakwood, with regard to potential they are rated as nonproductive, nonexploitable, nonuseable or negligible to speculative. Such resources are chalk, marl, limestone, glauconite, kaolinite clays, and industrial and specialty sands.

7.2 KEECHI DOME

The surface area overlying Keechi Dome is centered in the western portion of Anderson County, approximately 11 km (7 mi) northwest of the city of Palestine. The nearest permanent community is Montalba, about 4 km (2.5 mi) northwest of the dome, with a population of about 150.

The population density of the county is approximately 30 per square mile according to the latest census estimates. Most of the population is concentrated in the west-central portion, within the city of Palestine (32,500) and nearby rural areas. There are approximately 25 separate land owners within a 3-km (2-mi) radius of the center of Keechi Dome.

Numerous hydrocarbon wells drilled in the vicinity of Keechi Dome, along with the gravity model (Figure 7-11), provide the basis for geologic interpretation at Keechi.

7.2.1 DOME GEOMETRY AND COMPOSITION: The gravity model of Keechi Dome in plan view is an elongate ellipse, oriented with the long axis [7.2 km (4.5 mi) long)], trending north and 15 degrees east (Figure 7-11). The transverse axis is 2.7 km (1.7 mi) long. Above -1,524 meters (-5,000 ft) MSL, the dome has a broad, steep-sided base which tapers upward in profile (Figures 7-12 and 7-13). Regional gravity data indicate that Keechi Dome overlies the northern portion of a north-northeast-oriented elongate salt ridge along which Palestine, Concord, and possibly Butler Domes lie (Figure 6-9). The ridge is probably the source of salt for Keechi and the other domes along the ridge. Figures

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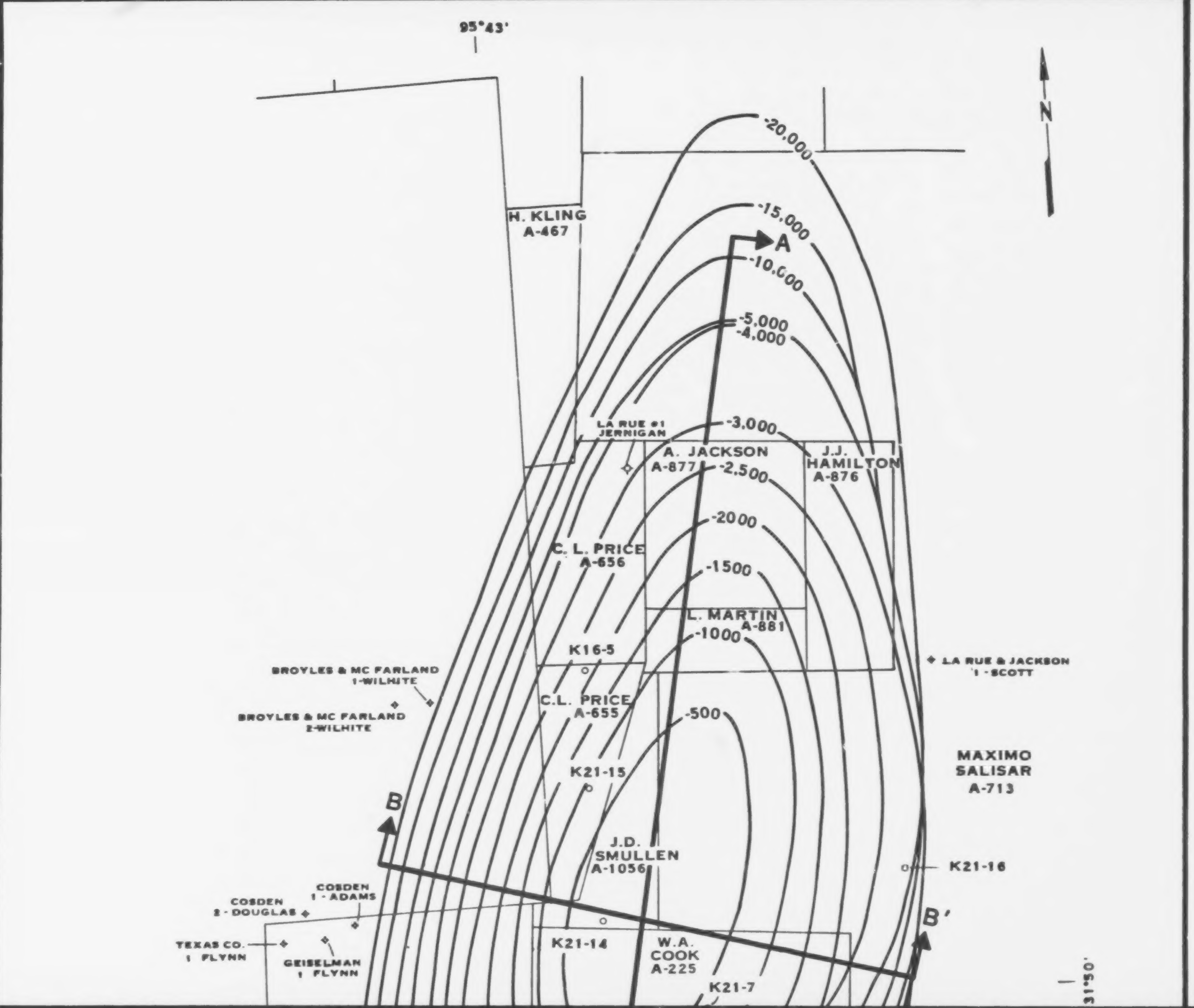
95°43'
N
-20,000
-15,000
A
-10,000
-5,000
-4,000
-3,000
-2,500
-2000
-1500
-1000
-500
H. KLING
A-467
LA RUE #1
JERNIGAN
A. JACKSON
A-877
J.J.
HAMILTON
A-876
C. L. PRICE
A-656
L. MARTIN
A-881
K16-5
BROYLES & MC FARLAND
1-WILHITE
BROYLES & MC FARLAND
2-WILHITE
LA RUE & JACKSON
1 - SCOTT
C.L. PRICE
A-655
K21-15
MAXIMO
SALISAR
A-713
B
J.D.
SMULLEN
A-1056
K21-16
COSDEN
1 - ADAMS
COSDEN
2 - DOUGLAS
B'
TEXAS CO.
1 FLYNN
GEISELMAN
1 FLYNN
K21-14
W.A.
COOK
A-225
K21-7
31°50'

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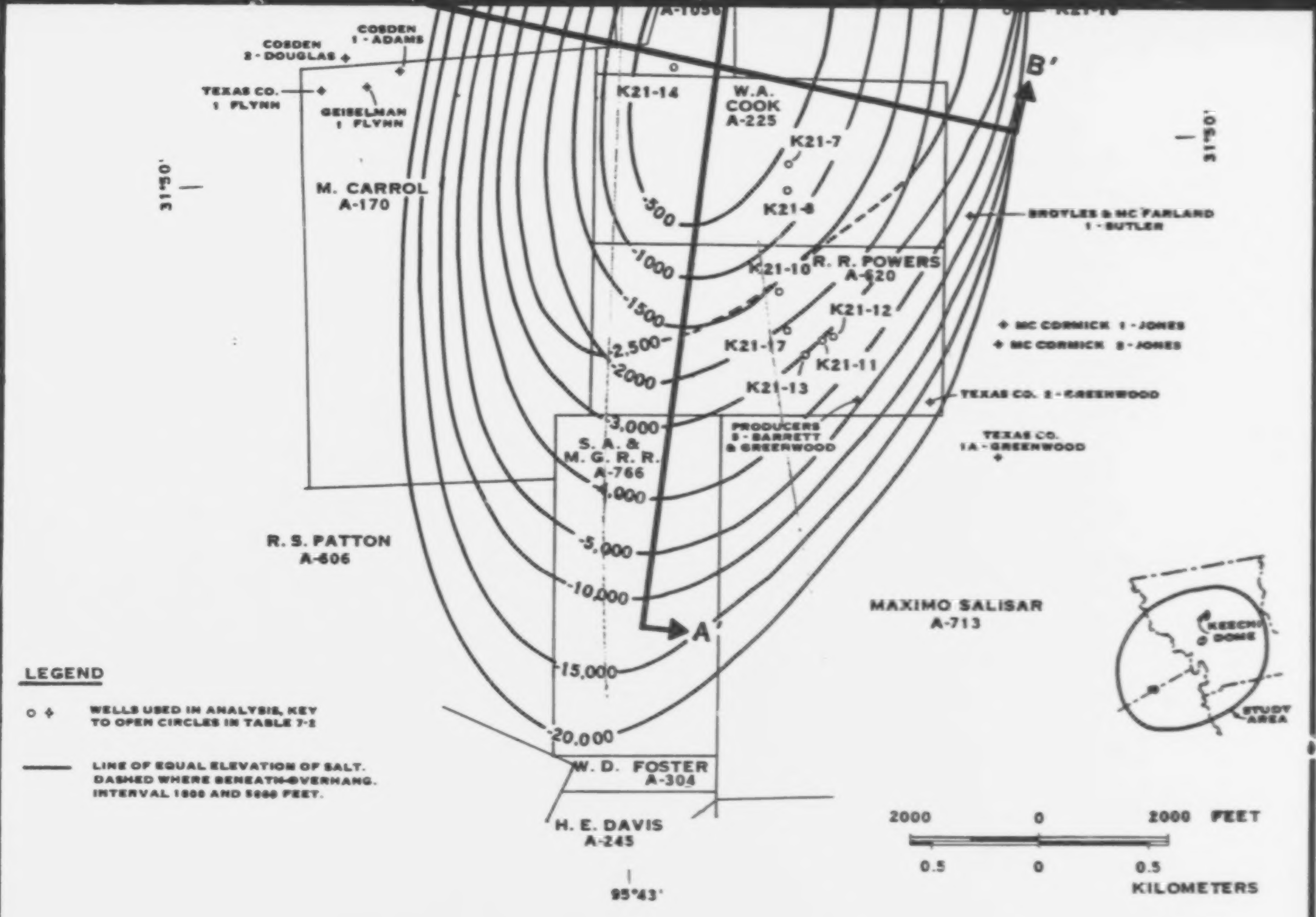
A-1056
K21-16
COSDEN
1 - ADAMS
COSDEN
2 - DOUGLAS
TEXAS CO.
1 FLYNN
GEISELMAN
1 FLYNN
K21-14
W.A. COOK
A-225
B'
31°50'
31°50'
K21-7
M. CARROL
A-170
500
K21-8
BROYLES & MC FARLAND
1 - BUTLER
1000
K21-10
R. R. POWERS
A-620
1500
K21-12
MC CORMICK 1 - JONES
MC CORMICK 2 - JONES
2,500
K21-17
2000
K21-11
K21-13
TEXAS CO. 2 - GREENWOOD
3,000
PRODUCERS
3 - BARRETT
& GREENWOOD
TEXAS CO.
1A - GREENWOOD
S. A. &
M. G. R. R.
A-766
4,000
R. S. PATTON
A-606
5,000
10,000
MAXIMO SALISAR
A-713
KEECHI DOME
A'
15,000
STUDY AREA
20,000
W. D. FOSTER
A-304
H. E. DAVIS
A-245
95°43'
2000
0
2000
FEET
0.5
0
0.5
KILOMETERS
LEGEND
○ ◆ WELLS USED IN ANALYSIS, KEY TO OPEN CIRCLES IN TABLE 7-2
LINE OF EQUAL ELEVATION OF SALT. DASHED WHERE BENEATH OVERHANG. INTERVAL 1000 AND 5000 FEET.

FIGURE 7-11

PREPARED 9H DATE 8/15/80
REVISED DF DATE 11/11/81
REVISED DATE
APPROVED EWE DATE 8/15/80
T-1125-2

NATIONAL WASTE TERMINAL
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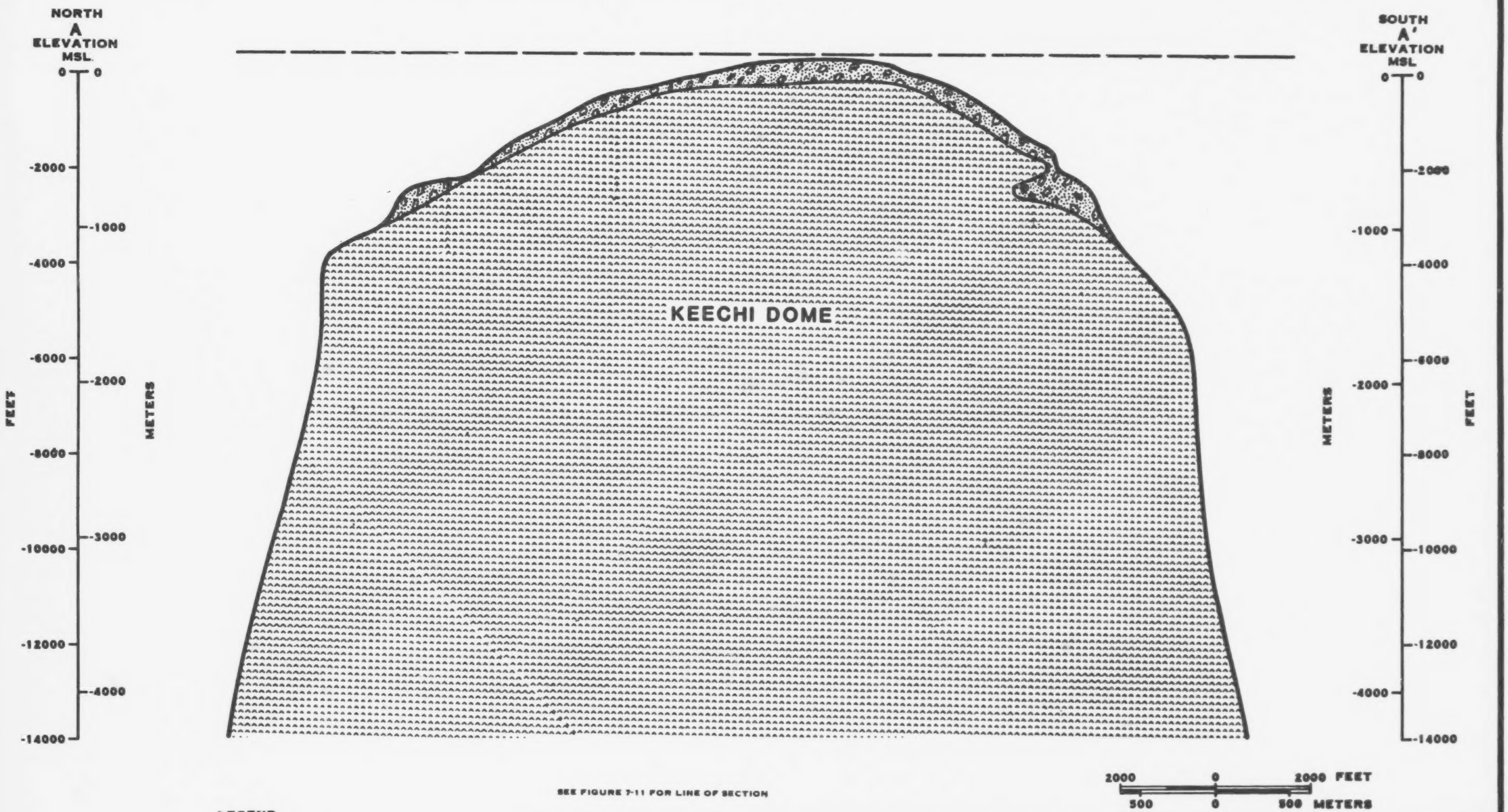
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME
SALT STRUCTURE MAP
AND WELL LOCATION

JOB NO. MV9600 FIGURE 7-11


NORTH
A
ELEVATION
MSL.
0
0
-2000
-1000
-4000
-6000
-2000
FEET
METERS
-8000
-3000
-10000
-12000
-4000
-14000
KEECHI DOME
SOUTH
A'
ELEVATION
MSL.
0
0
-2000
-1000
-4000
-6000
-2000
METERS
FEET
-8000
-3000
-10000
-12000
-4000
-14000
2000
0
2000 FEET
500
0
500 METERS

SEE FIGURE 7-11 FOR LINE OF SECTION

LEGEND

▨ CAPROCK

▤ SALT

PREPARED FH DATE ______
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED DGP DATE 11/17/81
T-1860-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME
CROSS SECTION A - A'

JOB NO. MV9600

FIGURE 7-12

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

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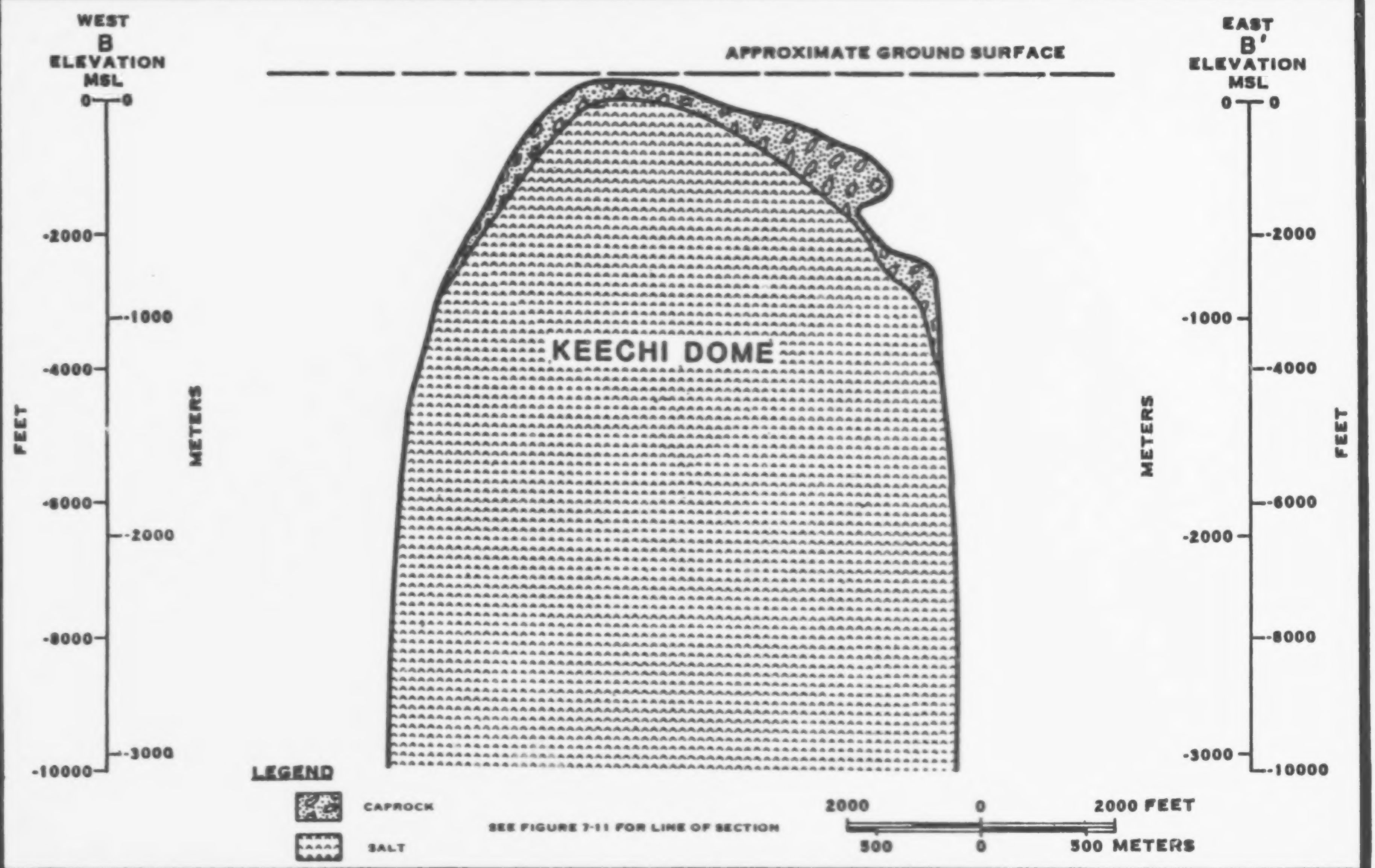
WEST
B
ELEVATION
MSL
EAST
B'
ELEVATION
MSL
APPROXIMATE GROUND SURFACE
KEECHI DOME
FEET
METERS
0
-2000
-4000
-6000
-8000
-10000
-1000
-2000
-3000
LEGEND
CAPROCK
SALT
SEE FIGURE 7-11 FOR LINE OF SECTION
2000
0
2000 FEET
500
0
500 METERS

PREPARED F.H. DATE

REVISED DATE

REVISED DATE

APPROVED DATE 4/17/81

T-1127-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM

GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME
CROSS SECTION B - B'

JOB NO. MV9600

FIGURE 7-13

FIGURE 7-13

7-11 and 7-14 illustrate the overhang as determined by gravity modeling for both salt and the caprock. Area calculations from the gravity model of the salt (Figure 7-11) indicate that the dome encompasses 478, 560, and 838 hectares (1,180, 1,385 and 2,070 acres) at -610, -762, and -914 meters (-2,000, -2,500 and -3,000 ft) MSL, respectively.

Caprock at Keechi Dome, according to the structure contour map based on the gravity model (Figure 7-14), covers the dome top and extends out to the steep-sided domal flanks to -914 meters (-3,000 ft) MSL, oriented parallel to the long axis. The depth to caprock over the dome ranges from 38 meters (25 ft) in the Navarro No. 2 Greenwood (LETCo K21-14) well, to 1,083 meters (3,553 ft) in the LaRue No. 1 Jernigan (LETCo 12-10) well [-69 to -934 meters (-225 to -3,066 ft) MSL (Figure 7-11)]. The thickness of caprock is extremely irregular, ranging from 5 to >91 meters (16 to >300 ft) according to well data points. The salt structure map (Figure 7-11) and the caprock structure map (Figure 7-14) suggest that the caprock could be substantially thicker in the area of overhang on the southeast flank of the dome.

The surface of the salt at Keechi Dome is encountered at depths ranging from 133 to 1,126 meters (435 to 3,694 ft) [-26 to -978 meters (-85 to -3,208 ft) MSL]. No data are available bearing on the character of the salt; however, it is assumed to have a composition similar to that encountered in other interior salt domes, i.e., crystalline halite, 90 to 95 percent pure, with anhydrite as a major impurity.

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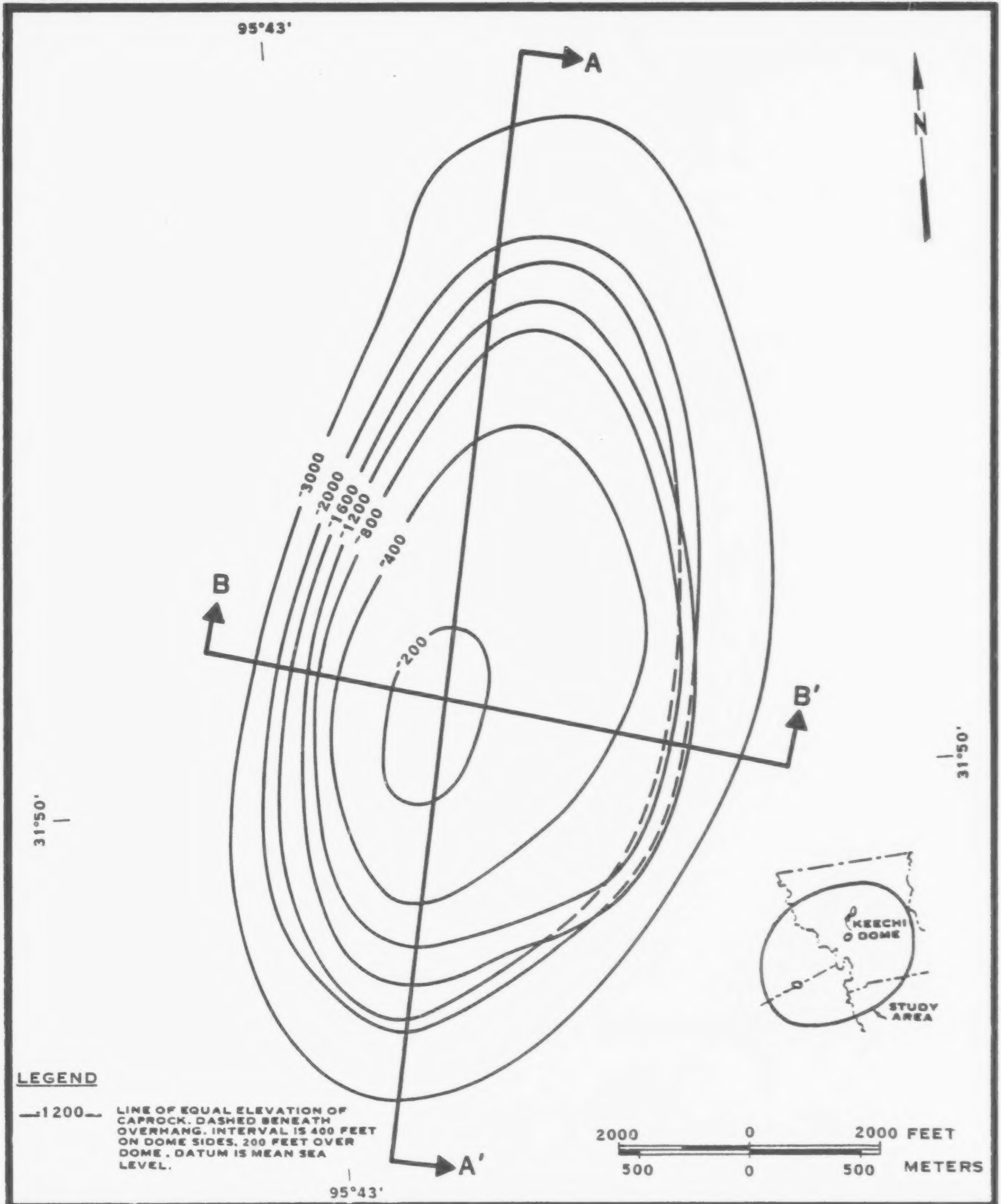
95°43'
A
N
-3000
-2000
-1600
-1200
-800
-400
-200
B
B'
31°50'
31°50'
KEECHI DOME
STUDY AREA
LEGEND
—1200— LINE OF EQUAL ELEVATION OF CAPROCK. DASHED BENEATH OVERHANG. INTERVAL IS 400 FEET ON DOME SIDES, 200 FEET OVER DOME. DATUM IS MEAN SEA LEVEL.
A'
95°43'
2000
0
2000 FEET
500
0
500
METERS

PREPARED ____ DATE ____
REVISED ____ DATE ____
REVISED ____ DATE ____
APPROVED ____ DATE ____
T-1128-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME
CAPROCK STRUCTURE MAP

JOB NO. MV9600 FIGURE 7-14

140 BEST DOCUMENT AVAILABLE

Exploration drilling at the dome has been limited to 9 wells (Table 7-2 and Figure 7-11) which passed through caprock to salt. These holes do not eliminate much of the useable area of the dome because they did not penetrate deeply into the salt.

7.2.2 NEAR-DOME GEOLOGY: This section includes a discussion of the surface and subsurface geology over and in the vicinity of Keechi Dome.

7.2.2.1 Surface Geology: The following paragraphs describe the physiographic characteristics, outcrop patterns, and structural features observed at the surface above Keechi Dome.

7.2.2.1.1 Physiography - Keechi Dome lies in the west-central portion of the Rolling Hills and Prairie Subprovince of the East Texas Timberland Physiographic Province (Fisher, 1965). Gently undulating topography, with a relief of 30 to 46 meters (100 to 150 ft), characterizes the general area (Figure 7-15). The relief is caused by differential erosion of the outcropping that consists of alternating sections of resistant and nonresistant beds. The adaptation of different types of vegetation to various lithologies tends to emphasize the effects of differential erosion.

Prominent physiographic features to the north and east of the Keechi domal area are cuestas with north-facing escarpments, known locally as the Ironstone Hills (Figure 6-6). These cuestas, protected by the indurated ironstone of the Weches

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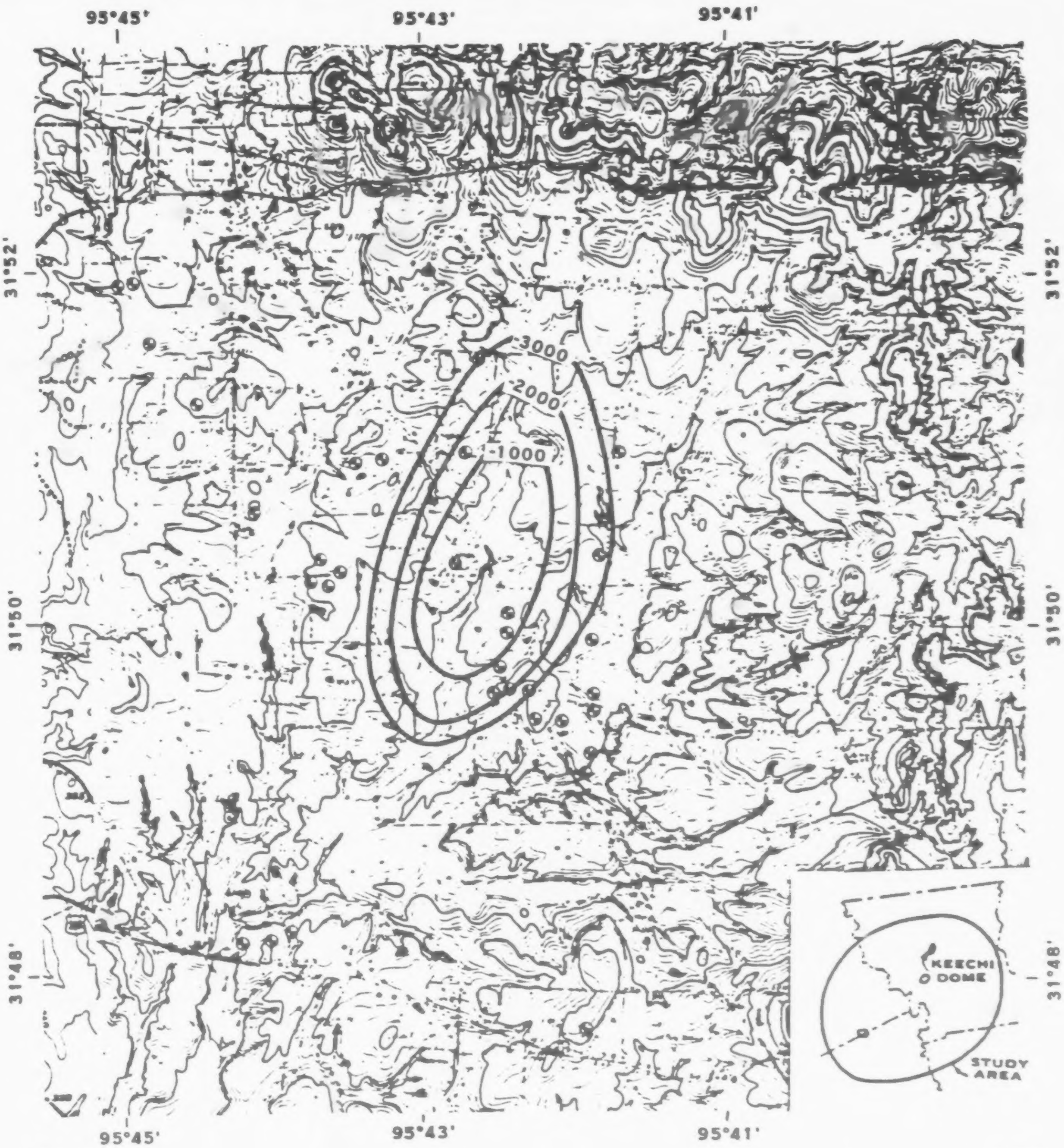
TABLE 7-2

KEECHI DOME BOREHOLE DATA SUMMARY

WELL NAME	LETCo WELL NO.	LOCATION[*]	ELEV. (MSL) G.L.(FT)	TOTAL DEPTH (FT)	LOGS[†] RUN	CASING DIA (OD)DEPTH	GROUTING	CASING SEAT DEPTH (FT)	ABANDONMENT PROCEDURE	ELEV. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (FT)	ELEV. (MSL) TOP SALT/ THICKNESS PENETRATED (FT)	SOURCE	REMARKS
Navarro #4 Greenwood	K16-5	Price Survey-2000' N of #3 (K21-15). 1000' FWL of Surv.	+422	2585	Driller's Log only.	10" - 40'	No Data	40	No Data	-2008/18 -1800/226	-2026	TBEG, TX Well Log Service Driller's Log. G. Greene (LETCo Consultant)	Drilled in 1926. Plugged & Abandoned
Navarro #3 Greenwood	K21-15	Price Surv. 790' FWL, 285' FSEL of Surv. 1632' NW of #2 in J.D. Smullen Surv.	+384	1371	Driller's Log only.	10" - 40'	No Data	40	No Data	-952'/16	-968/19	TBEG, TX Well Log Serv, Drlrs. Log, G. Greene	Drilled in 1926. Plugged & Abandoned
Navarro #2 Greenwood	K21-14	J.D. Smullen Surv. 93.7' FSL & 944' FEL of Surv.	+350	435	Driller's Log only.	10" - 150'	No Data	150	No Data	+225/310	-85/0	TBEG, TX Well Log Serv, Drlrs. Log, G. Greene	Drilled in 1926. Plugged & Abandoned
Thrash & Lloyd #1 Link	K21-7	Wm. A. Cook Surv. 1300' FNL, 2350' FEL of Surv.	+340	1071	Induction Electrical, Microelectrical, Radioactivity.	5 1/2" - 625'	Cement	625	No Data	No Data	-731	TBEG, G. Greene	Drilled in 1971. Plugged and Abandoned
Navarro #1 Greenwood	K21-8	Wm. A. Cook Surv. 1500' FNL & 2300' FEL of Surv.	+370	1363	Driller's Log only.	10" - 43' 6 5/8"-1310'	No Data	43 1310	No Data	-913'/72 -330/655	-985	TBEG, TX Well Log Serv, Drlrs. Log, G. Greene	Drilled in 1926. Plugged & Abandoned
Producer's #1 Barrett & Greenwood	K21-10	R.R. Powers Surv. 2400' FEL & 650' FNL of Surv.	+385	3170	Driller's Log only.	12 1/2"-149' 10"-821' 8 1/4"-1792' 6 1/4"-2844'	No Data	149 821 1792 2844	No Data	-1019/758	-1777 -2637 (BASE) -2713	TBEG, TX Well Log Serv, Drlrs. Log, G. Greene	Drilled in 1916 through overhang. Plugged & Abandoned
Producer's (Navarro) #1 Barrett	K21-17	R.R. Powers Surv. 2700' FWL & 1250' FSL of Surv.	+388	3503	Driller's Log, Sample Log	10" - 40' 6 5/8-2003'	No Data	40 2003	No Data	-1769/238 -1886	-2007	TBEG, TX Well Log Serv, Drlrs. Log, G. Greene	Drilled in 1926. Plugged Abandoned
Producer's #2 Barrett & Greenwood	K21-13	R.R. Powers Surv. 2000' FEL & 1000' FSL of Surv.	+350	2297	Driller's Log only.	11 1/2"-190' 10" - 1129' 8 1/4"-2049' 6 1/4"-2247'	No Data	190 1129 2049 2247	No Data	Caprock not reached.	Salt not reached.	TBEG, TX Well Log Serv, Drlrs. Log.	Drilled in 1916. Plugged & Abandoned
Producer's #6 Barrett & Greenwood	K21-11	R.R. Powers Surv. 1650' FEL & 1400' FNL. of Surv.	+400	2342	Driller's Log only.	No Data	No Data	No Data	No Data	Caprock not reached.	Salt not reached.	TBEG, TX Well Log Serv, Drlrs. Log.	Drilled in 1920's Plugged & Abandoned
Producer's #3 Barrett & Greenwood	K21-12	R.R. Powers Surv. 1500' FEL & 1400' FNL of Surv.	+400	2656	Driller's Long only.	12 1/2"-251' 10" - 1235' 8 1/4"-2367'	No Data	251 1235 2367	No Data	Caprock not reached.	Salt not reached.	TBEG, TX Well Log Serv, Drlrs. Log, G. Greene	Drilled in 1916. Plugged & Abandoned
Navarro (Sun) #1 Gardner	K21-16	Maximo Salisar Surv. 1150' FNL & 150' FEL of Surv.	+418	3364	Driller's Log only.	10" - 406'	No Data	406	No Data	-2774/38 -2424/388	-2812	TBEG, TX Well Log Serv. Drlrs. Log.	Drilled in 1900. Plugged & Abandoned

[*] FNL, FWL, FSEL, etc.: F=from; N, W, SE, etc. = direction; L=Line.

[†] Geophysical log. This is a continuous log of some physical property, such as resistivity, density, temperature, of rock material obtained by lowering an instrument into a borehole.


95°45'
95°43'
95°41'
31°52'
31°50'
31°48'
N
3000
2000
1000
KEECHI DOME
STUDY AREA

LEGEND

—— -1000 —— LINE OF EQUAL ELEVATION OF SALT. INTERVAL IS 1000 FEET. DATUM IS MEAN LEVEL.

● OIL OR GAS WELL

1 0 1 MI

1 0 1 KM

CONTOUR INTERVAL IS 20 FEET.
DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY
1: 24,000 QUADRANGLE.

PREPARED ____ DATE ____
REVISED FH DATE ____
REVISED ____ DATE ____
APPROVED ____ DATE 11/7/
T-2090-0

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME AREA
TOPOGRAPHIC MAP AND DATA UTILIZED IN ANALYSIS

JOB NO. MV9600 FIGURE 7-15

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Formation, present a distinctive relief which is in sharp contrast to that of the less rugged topography of the surrounding area (Ebanks, 1965).

The surface at Keechi is distinguished by a topographically low area surrounded by a ring of hills with a radius of about 1.6 to 2.4 km (1 to 1.5 mi) from the center of the dome. These hills are remnants of cuestal slopes that dip outward from elevations as high as 152 meters (500 ft) on the north side of the dome and ranging from 122 to 137 meters (400 to 450 ft) on the east and west sides. The elevations of the central area range from 98 to 110 meters (320 to 360 ft).

The southern and western portions of the domal area are drained by Lake Creek, Six Mile Creek, and Keechie Creek (Figure 7-16). Elevations along the stream beds are below 91 meters (300 ft).

Outward from the ring of hills surrounding the dome, the land surface rises gently to the north and east. Approximately 5 km (3 mi) from the dome the land surface rises sharply at a point where the Weches Formation forms the lip of the prominent system of cuestas. Elevations along these cuestas reach as high as 213 meters (700 ft), creating up to 122 meters (400 ft) of relief in the domal area.

7.2.2.1.2 Outcropping Geologic Units - The beds exposed within the domal area include those of Cretaceous, Tertiary, and Quaternary age (Figure 7-17). The Cretaceous System is represented by the Taylor and Navarro Groups of the upper Gulfian Series.

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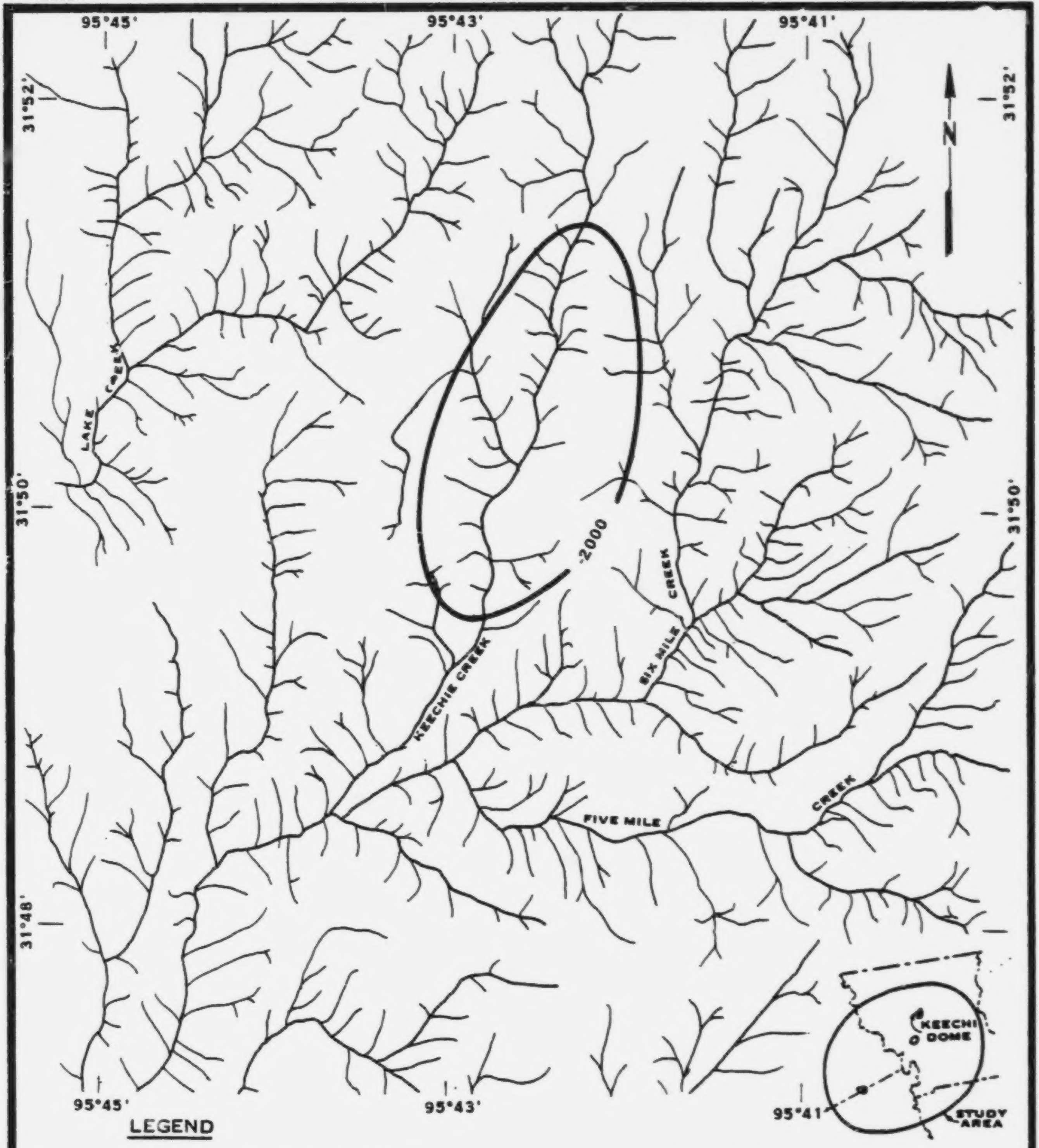
95°45'
95°43'
95°41'
31°52'
31°50'
31°48'
N
LAKE CREEK
KEECHIE CREEK
-2000
SIX MILE CREEK
FIVE MILE CREEK
KEECHI DOME
STUDY AREA

LEGEND

-2000 LINE OF EQUAL ELEVATION OF SALT. DATUM IS MEAN SEA LEVEL

STREAM

4000 0 4000 FEET

1000 0 1000 METERS

BASE FROM U.S. GEOLOGICAL SURVEY 1:24,000 QUADRANGLE

PREPARED CDI DATE [illegible]
REVISED [illegible] DATE [illegible]
REVISED ______ DATE ______
APPROVED [illegible] DATE [illegible]
T-1133-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
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EAST TEXAS STUDY AREA

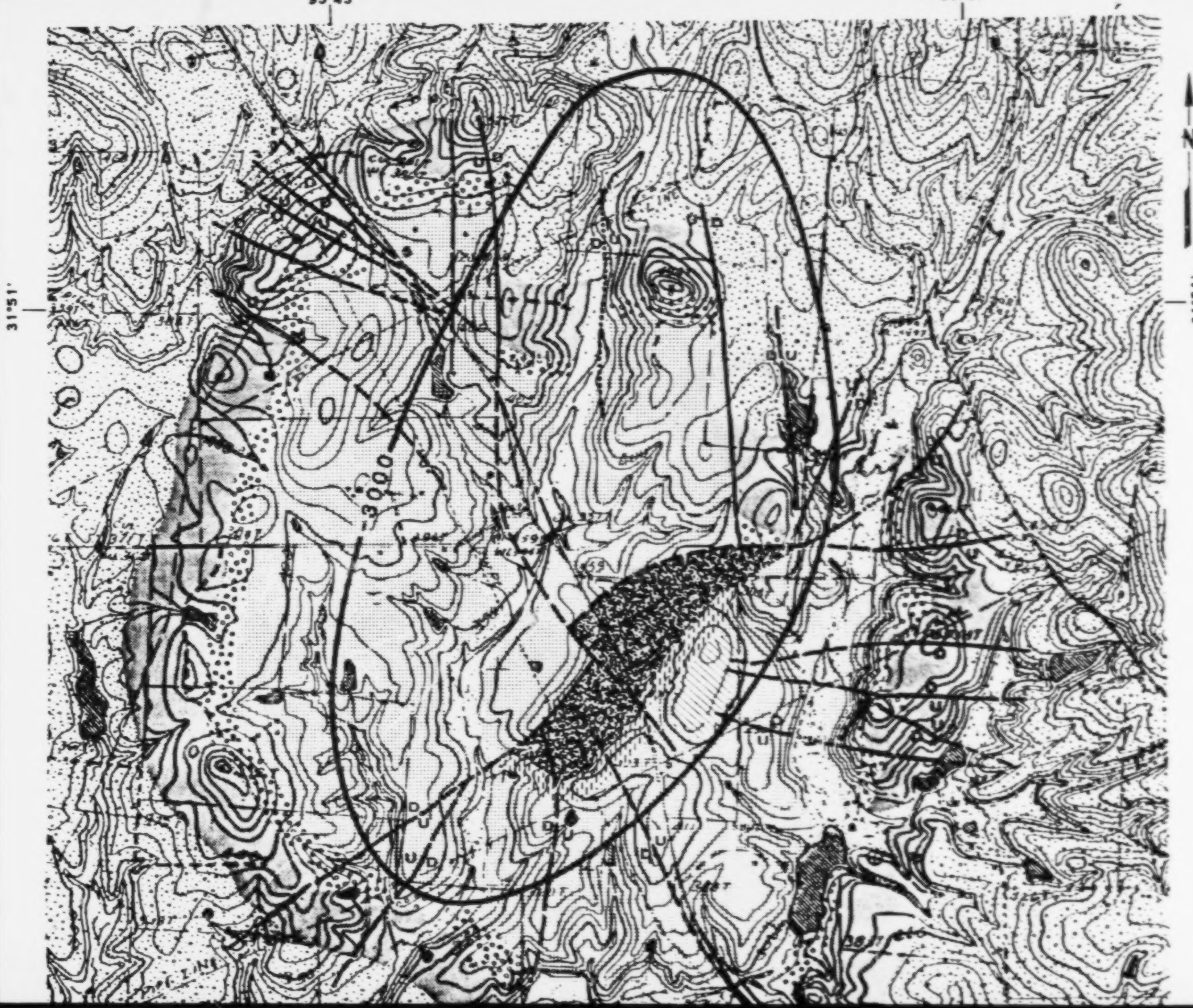
KEECHI DOME AREA DRAINAGE NETWORK

JOB NO. MV9600 FIGURE 7-15

145 BEST DOCUMENT AVAILABLE

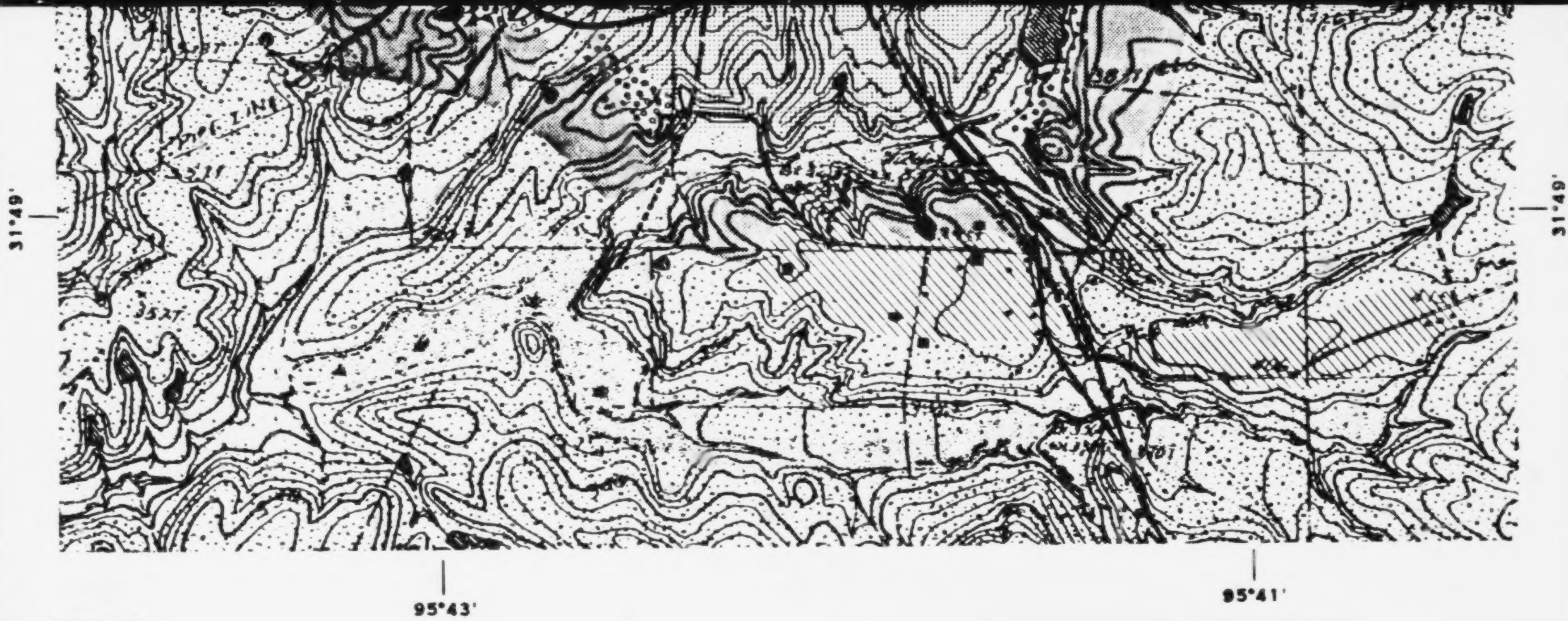
DOCUMENT AVAILABLE

146


95°43'
95°41'
31°51'
31°51'
N
3000
D
U

BEST DOCUMENT AVAILABLE

146



LEGEND

QUATERNARY	PLEISTOCENE & RECENT		░	ALLUVIUM
			▨	UPLAND TERRACE DEPOSITS
TERTIARY	EOCENE	CLAIBORNE	⁘	QUEEN CITY FORMATION
			■	REKLAW FORMATION
			○	CARRIZO FORMATION
		WILCOX	□	WILCOX GROUP (UNDIFFERENTIATED)
CRETACEOUS	PALEOCENE	MIDWAY	▥	MIDWAY GROUP (UNDIFFERENTIATED)
	GULFIAN	TAYLOR & NAVARRO	▓	TAYLOR - NAVARRO GROUPS (UNDIVIDED)

U / D FAULT-UPTHROWN/DOWNTHROWN

DASHED WHERE INFERRED

FAULT DOTTED WHERE COVERED

× PIT OR QUARRY

-3000 LINE OF EQUAL ELEVATION OF SALT. DATUM IS MEAN SEA LEVEL.

PONDS AND LAKES

ROAD OR HIGHWAY

KEECHI DOME
STUDY AREA

2000
0
2000
FEET
500
0
500
METERS

CONTOUR INTERVAL IS 20 FEET. DATUM IS MEAN SEA LEVEL. BASE FROM U.S. GEOLOGICAL SURVEY 1:24,000 QUADRANGLE.

GEOLOGIC MAPPING BY LETCO, 1981 AND EBANKS, 1965

PREPARED ________ DATE ________

REVISED ________ DATE ________

REVISED ________ DATE ________

APPROVED ________ DATE ________

T-1134-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME
GEOLOGIC MAP

JOB NO. MV9600

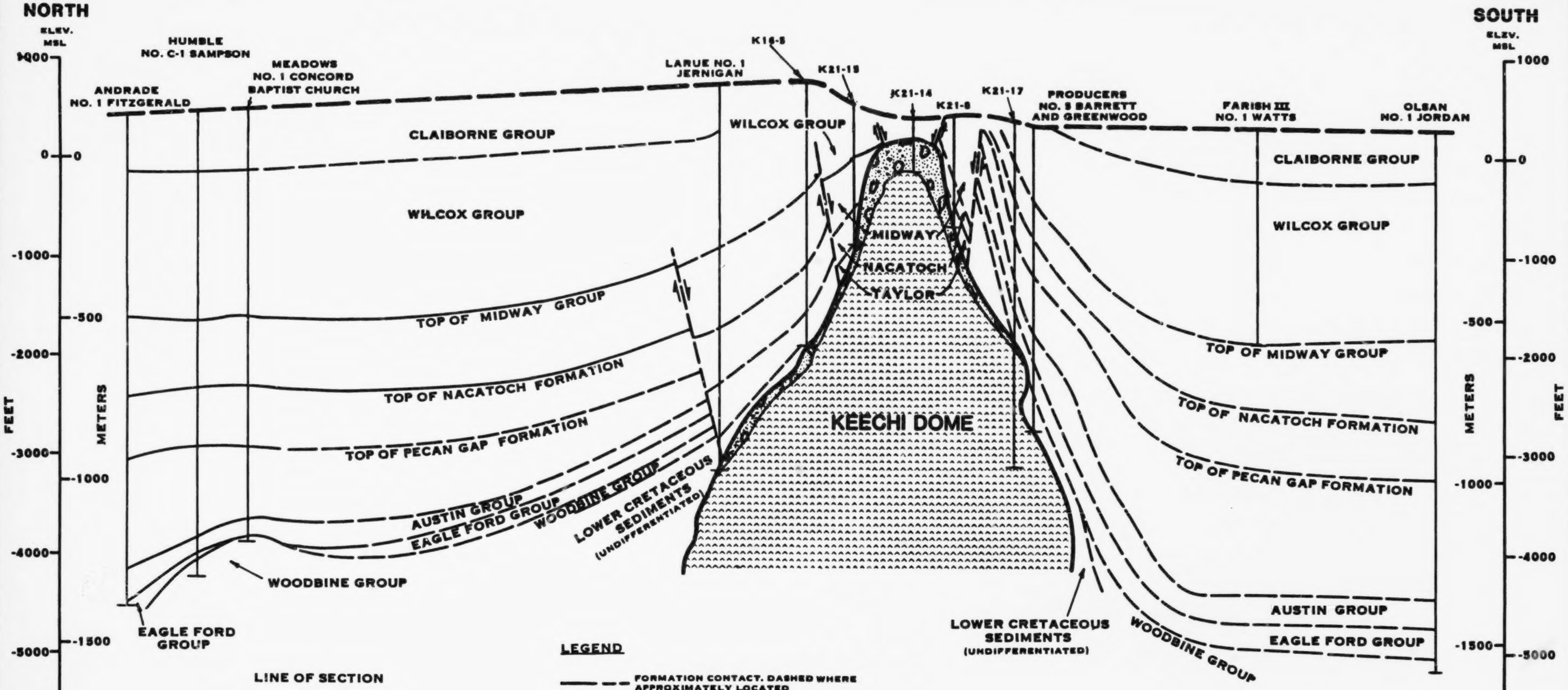
FIGURE 7-17

FIGURE 7-17

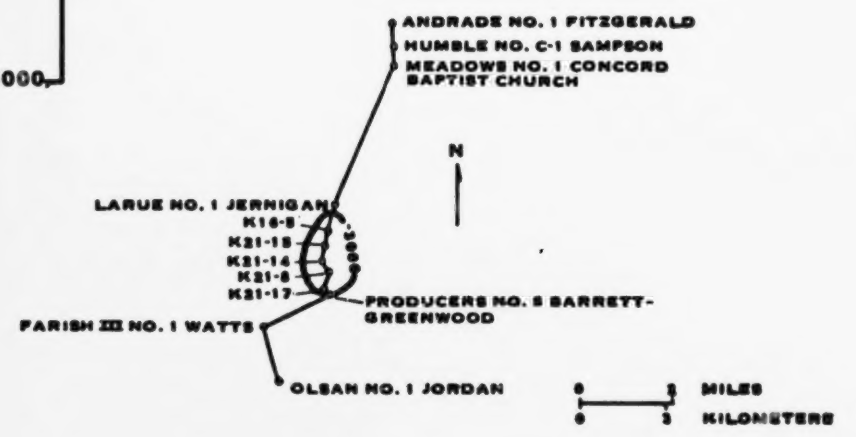
The Tertiary System here includes the Midway Group of the Paleocene Series, the Wilcox Group of the late Paleocene-early Eocene Series and the Claiborne Group of the Eocene Series. The Claiborne Group consists of the Carrizo, Reklaw, Queen City, Weches, and Sparta Formations. The Quaternary sediments are represented by alluvial terrace remnants and floodplain deposits along the major streams in the area. The following summary of outcropping geologic units is largely taken from Ebanks (1965). Detailed descriptions of lithology and chronology of the stratigraphic units have been presented in Chapter 6, Section 6.2.2, and they are shown in Table 6-1.

The Upper Cretaceous beds exposed at Keechi consist of the Taylor and Navarro Groups of the Gulfian Series; however, the contact between the groups is not exposed (Ebanks, 1965). Because of the similarity of the units and poor exposure, the LETCo (1981b) map does not differentiate between the Cretaceous Taylor and Navarro Groups (Figure 7-17).

The oldest exposed unit is represented by the Pecan Gap Formation, which is identified by chalky limestone fragments and marly clays. At the center of the dome, about 183 meters (600 ft) west of Highway 19 in a small gully, the Pecan Gap has been brought to the surface as a result of dome growth and associated faulting (Ebanks, 1965). This area of exposure of Cretaceous deposits, which Ebanks mapped near the center of the dome, was extended on the basis of field checking and soil type (LETCo, 1981b) (Figure 7-17). Figure 7-18 shows thinning of the Pecan Gap towards Keechi Dome. Preliminary isochore maps from BEG and


NORTH
ELEV. MSL
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
FEET
0
-500
-1000
-1500
METERS
ANDRADE NO. 1 FITZGERALD
HUMBLE NO. C-1 SAMPSON
MEADOWS NO. 1 CONCORD BAPTIST CHURCH
LARUE NO. 1 JERNIGAN
K16-5
K21-15
K21-14
K21-8
K21-17
PRODUCERS NO. 5 BARRETT AND GREENWOOD
FARISH III NO. 1 WATTS
OLSAN NO. 1 JORDAN
SOUTH
ELEV. MSL
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
FEET
0
-500
-1000
-1500
METERS
CLAIBORNE GROUP
WILCOX GROUP
WILCOX GROUP
TOP OF MIDWAY GROUP
TOP OF NACATOCH FORMATION
TOP OF PECAN GAP FORMATION
AUSTIN GROUP
EAGLE FORD GROUP
WOODBINE GROUP
LOWER CRETACEOUS SEDIMENTS (UNDIFFERENTIATED)
WOODBINE GROUP
EAGLE FORD GROUP
MIDWAY
NACATOCH
TAYLOR
KEECHI DOME
CLAIBORNE GROUP
WILCOX GROUP
TOP OF MIDWAY GROUP
TOP OF NACATOCH FORMATION
TOP OF PECAN GAP FORMATION
LOWER CRETACEOUS SEDIMENTS (UNDIFFERENTIATED)
AUSTIN GROUP
EAGLE FORD GROUP
WOODBINE GROUP

LINE OF SECTION


ANDRADE NO. 1 FITZGERALD
HUMBLE NO. C-1 SAMPSON
MEADOWS NO. 1 CONCORD BAPTIST CHURCH
N
LARUE NO. 1 JERNIGAN
K16-5
K21-15
K21-14
K21-8
K21-17
PRODUCERS NO. 5 BARRETT-GREENWOOD
FARISH III NO. 1 WATTS
OLSAN NO. 1 JORDAN
0 3 MILES
0 3 KILOMETERS

LEGEND

— — FORMATION CONTACT, DASHED WHERE APPROXIMATELY LOCATED

FAULT-ARROWS INDICATE DIRECTION OF RELATIVE MOVEMENT

INFERRED FAULT

▨ SALT

▨ CAPROCK

4000 0 4000 FEET

1000 0 1000 METERS

VERTICAL EXAGGERATION 4X
WELL KEY IN TABLE 7-2

MODIFIED FROM THE TEXAS BUREAU OF ECONOMIC GEOLOGY, 1980

PREPARED	FH	DATE	
REVISED		DATE	
REVISED		DATE	
APPROVED	OAP	DATE	11/7/81

T-2097-0

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME
GEOLOGIC CROSS SECTION

JOB NO. MV9600

FIGURE 7-18

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cross sections derived from seismic data (Figure 7-19) also confirm the thinning of the Lower Taylor and Upper Navarro towards the dome. The Pecan Gap is a carbonate shelf-type deposit. The Upper Taylor consists of microfossiliferous marl and slightly calcareous shale. The thickness of the Taylor Group at the surface of the dome is approximately 183 meters (600 ft). In the Pure No. 1 City of Palestine (LETCo 20-5) well (Figure 7-19) it is 366 meters (1,200 ft) thick at an elevation of -914 meters (-3,000 ft) MSL [1,036 meters (3,400 ft) below ground level].

The Navarro Group is divided into the Lower Navarro, Nacatoch, and Upper Navarro Formations. At the surface, the Navarro Group has a semicircular outcrop pattern to the east of the Taylor outcrop. Where exposed, the Navarro units are dark gray clays with occasional limestone concretions and calcareous nodules. Surface exposures at the dome are 61 to 76 meters (200 to 250 ft) thick. A north-south cross section over Keechi Dome (Figure 7-18) shows thinning of the Nacatoch Sand towards the dome. At depth, Well 20-5 (Figure 7-19) shows the thickness of the Navarro Group to be approximately 152 meters (500 ft). The clays of the Navarro Group were deposited under deep marine to shallow neritic conditions.

At Keechi Dome the Midway Group, which is part of the Paleocene Series, is exposed to the east of the Navarro outcrop. Subsoils and topsoils are generally sandy clays, frequently containing ironstone pebbles or concretions. In Well 20-5, (Figure 7-19) the unit is 174 meters (570 ft) thick. Figure 7-19 indicates that the beds of the Midway Group thin toward the dome. At

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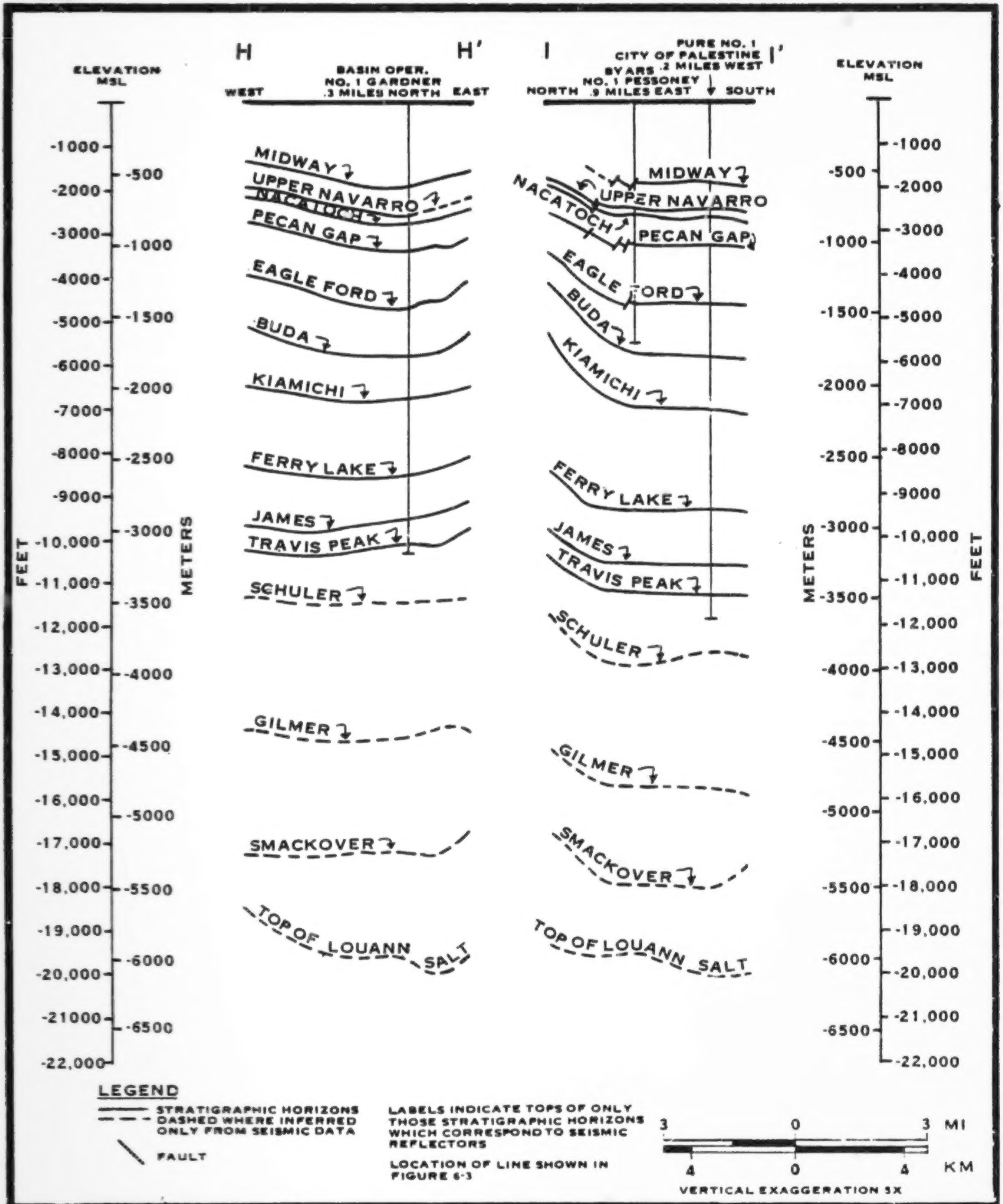
H
H'
I
I'
ELEVATION MSL
WEST
BASIN OPER. NO. 1 GARDNER .3 MILES NORTH
EAST
NORTH
BYARS NO. 1 PESSONEY .9 MILES EAST
PURE NO. 1 CITY OF PALESTINE .2 MILES WEST
SOUTH
MIDWAY
UPPER NAVARRO
NACATOCH
PECAN GAP
EAGLE FORD
BUDA
KIAMICHI
FERRY LAKE
JAMES
TRAVIS PEAK
SCHULER
GILMER
SMACKOVER
TOP OF LOUANN SALT
FEET
METERS
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
-11,000
-12,000
-13,000
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-3500
-4000
-4500
-5000
-5500
-6000
-6500
LEGEND
STRATIGRAPHIC HORIZONS DASHED WHERE INFERRED ONLY FROM SEISMIC DATA
FAULT
LABELS INDICATE TOPS OF ONLY THOSE STRATIGRAPHIC HORIZONS WHICH CORRESPOND TO SEISMIC REFLECTORS
LOCATION OF LINE SHOWN IN FIGURE 6-3
3
0
3
MI
4
0
4
KM
VERTICAL EXAGGERATION 5X

PREPARED	DATE
REVISED	DATE
REVISED	DATE
APPROVED	DATE

T-1459-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM

GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME AREA
CROSS-SECTION H-H' AND I-I'
BASED ON SEISMIC AND WELL DATA

JOB NO. MV9600

FIGURE 7-19

BEST DOCUMENT AVAILABLE

150

the dome the Midway outcrop is estimated to be 30 to 61 meters (100 to 200 ft) thick. The depositional environment of the Midway marine sediments was shallow to deep neritic, similar to those of the underlying Navarro Group.

The Wilcox Group*, consisting of late Paleocene and early Eocene beds, is a heterogeneous sequence of fluvial-deltaic facies. Although the Wilcox is most prominently exposed in the area of the dome (Figure 7-17), it is generally covered with heavy vegetation and it is mapped as a single unit over Keechi Dome. Wilcox sediments in the dome area are both cross-bedded and plane-bedded, consisting of sands and silts interbedded with carbonaceous and lignitic clays. In some portions of the section the Wilcox Group contains layers cemented by limonite derived from the weathering of small amounts of disseminated glauconite. The Wilcox forms a loose sandy topsoil. Figure 7-18 illustrates upturning and thinning of the Wilcox units towards Keechi.

The Wilcox Group in Well K16-2, about 1.6 km (1 mi) north of the dome, consists of a zone of fissile claystone with thinly interbedded sand and siltstone below a massive sand approximately 61 meters (200 ft) thick. Overlying the sand is a sandy siltstone, approximately 91 meters (300 ft) thick. A preliminary isochore map of the Wilcox (BEG, 1980) shows that within the supradomal area the section thickens to the southeast and southward, apparently because of the influence of salt withdrawal into Palestine Dome.

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*The lowermost portion of the Wilcox Group is considered late Paleocene, whereas the upper beds are early Eocene.

The Eocene Claiborne Group in the domal area consists of (from oldest to youngest) the Carrizo, Reklaw, Queen City, Weches, and Sparta Formations. These formations are not exposed directly over the dome (Figure 7-17).

The Carrizo Formation consists of interbedded sand, silt, and clay, and the basal portion is conglomeratic in places, with shale and ironstone pebbles and cobbles reworked from the underlying Wilcox beds. The lower portion of the Carrizo consists of friable, cross-bedded to massively bedded, fine to medium-grain, clean sand. The bedding in this lower portion becomes increasingly lenticular upward as the grain size decreases. The upper portion of the Carrizo Formation is composed of interbedded carbonaceous clays and silts. The upper Carrizo represents a marine transgression, as alluvial deposition was followed by deltaic-lagoonal conditions. Surface outcrops at the dome are about 24 to 30 meters (80 to 100 ft) thick, but in nearby Well K16-2, the thickness of the Carrizo is approximately 52 meters (170 ft). The Carrizo weathers to a loose, sandy topsoil and a sandy clay subsoil.

Two distinctive units of the Reklaw Formation are exposed at Keechi. The lower is a silty, glauconitic, cross-bedded sand, overlain by glauconitic, calcareous clay, representing an offshore marine bar deposit, transitional northward and northwestward to a shallow, lagoonal facies, and southward and southeastward to an open, shallow neritic facies (Ebanks, 1965). This unit contains prominent concretionary ironstone layers which are excellent markers for recognizing fault displacements.

Weathering of the lower unit forms a loose, sandy soil, usually with scattered cobbles of hard ironstone. The upper unit represents a restricted marine facies and weathers to a loose, sandy topsoil and sandy clay subsoil. The lower unit, which ranges from 21 to 30 meters (70 to 100 ft) in thickness, is exposed extensively west of Keechi Dome.

The Queen City Formation consists of discontinuous, lenticular sands and interbedded clays. The sands are typically cross-bedded, micaceous, and slightly ironstained with some lignite and limonite. The Queen City forms a loose, sandy soil. The topsoil is commonly clean sand and the subsoils are clayey sand. The Queen City averages 91 meters (300 ft) thick and represents a transgressive fluvial to deltaic facies.

The Weches Formation is a marly, shelf facies, disconformably overlying the Queen City. The Weches typically consists of soft, glauconitic, fossiliferous clays with a few thin sand and limestone stringers. The Weches commonly weathers to a clay soil with scattered fragments of hard, ferruginous sandstone and claystone.

The Sparta Formation is exposed in small patches, discontinuously capping the cuestas to the north and east of the domal area. Here, representing a deltaic transgression over the Weches muds, the Sparta consists of soft, very fine to fine-grain sands with some silt and occasional lignitic clay partings weathering to a loose sand.

The Quaternary sediments in the domal area consist of Pleistocene terrace deposits located off the south flank (Figure 7-17) and Recent floodplain deposits found along most streams over the dome (Kreitler and others, 1980). The terrace deposits, similar to those described at Oakwood Dome (Sec. 7.1.2.1.2), consist of sandy clay to medium-grain sand with a few pebbles; they are generally less than 6 meters (20 ft) thick. The Recent alluvium is chiefly composed of clayey sands and sandy clays ranging in thickness up to 6 meters (20 ft). Gravels containing quartz, chert, and ironstone occur at some locations, and limestone gravels are present as float in the stream beds which have cut through the Taylor outcrop near the center of the domal area.

Tertiary sediments around and over the dome have been arched and truncated by erosion, forming a concentric, roughly elliptical outcrop pattern typical of inliers, with the older beds exposed closest to the dome center. Dips as high as 30 degrees are mapped in the Wilcox, north of the center of the dome. Dips gradually decrease outward from the dome center for about 3 km (2 mi), then into a regional, southeasterly dip of 1 or 2 degrees.

Observations at the outcrop indicate some thinning over the dome in Tertiary sediments; however, beds of the Claiborne Group show less thinning than those of the Wilcox. Tertiary sedimentation appears to have been continuous over the dome during salt movement.

The structurally highest part of the area is just south of the center of the dome where Upper Cretaceous and Paleocene sediments are exposed as an inlier in an elliptical pattern complicated by faulting (Figure 7-17). Dips measured on these outcrops range from 45 to 75 degrees, though there is often a wide variation in dips between adjacent outcrops, probably caused by drag folding and distortion of beds along the fault planes.

7.2.2.1.3 Structure - Keechi Salt Dome is characterized by steep quaquaversal flanks created by the rising salt plug. A maximum structural relief of about 1,341 meters (4,400 ft) is recorded in the Eagle Ford (Figure 7-18).

The fault pattern in the Keechi Dome is dominantly radial (Figure 7-17). Uplift and consequent attenuation of beds overlying and surrounding the salt are reflected in the characteristic pattern of high-angle to moderately dipping, normal faults. The typical condition over the dome is the alternation of upthrown and downthrown wedge-shaped fault blocks, narrowing toward the center of uplift. The offsets of the prominent basal Reklaw ironstone ledges along the ring of low cuestas around the dome are a reflection of these structural relationships.

Fault displacement is greatest near the center of the dome, decreasing outward until the effects of faulting become imperceptible about 3 km (2 mi) from the center of the dome. Maximum displacement has been calculated to be about 457 meters (1,500 ft), measured on the base of the Wilcox along the major fault which crosses the south-central part of the dome from northeast to southwest (Figure 7-17). Other faults commonly have throws ranging from 15 to 91 meters (50 to 300 ft) on the base of the Reklaw.

Minor erosional features, such as gullies developed in the intermittent drainage, delineate some of the major faults at the surface. Some lineaments interpreted from topographic maps of the domal area (Figure 7-20) appear to reflect some minor faults.

Two parallel cracks have been observed in the soil cover at Keechi Dome. Local inhabitants report that the cracks first appeared during the spring of 1978; however, the first documented observations began in November 1979 (Kreitler and others, 1980). Since that time, erosional processes appear to have gradually filled in the cracks with sand and leaves. The cracks occur near the southeastern extension of an inferred fault (tentatively mapped by Ebanks, 1965) near the dome's center. These cracks are nearly vertical with lengths of 29 and 12 meters (94 and 40 ft). The maximum width for the longer crack is about 36 mm (1.4 in). The exact depth of these features is not known; however, the base of the larger crack was not reached at a depth of 0.9 meter (3 ft), and depths of up to 4 meters (13 ft) have been reported. The upper 0.9 meter (3 ft) of soil in the walls of the cracks are composed of bands of varying colors of clay. No offset has been observed along the cracks, and any relationship of the fractures to the inferred (Ebanks, 1965) fault is unsubstantiated.

7.2.2.2 Subsurface Geology: Over 4,572 meters (15,000 ft) of Mesozoic and Cenozoic sedimentary rocks makes up the geologic column penetrated in the vicinity of Keechi Dome. The section includes the beds of the Late Triassic Series, Early and Late Jurassic Series, the Comanchean and Gulfian Series of the Cretaceous, and the Paleocene and Eocene Series of the Tertiary

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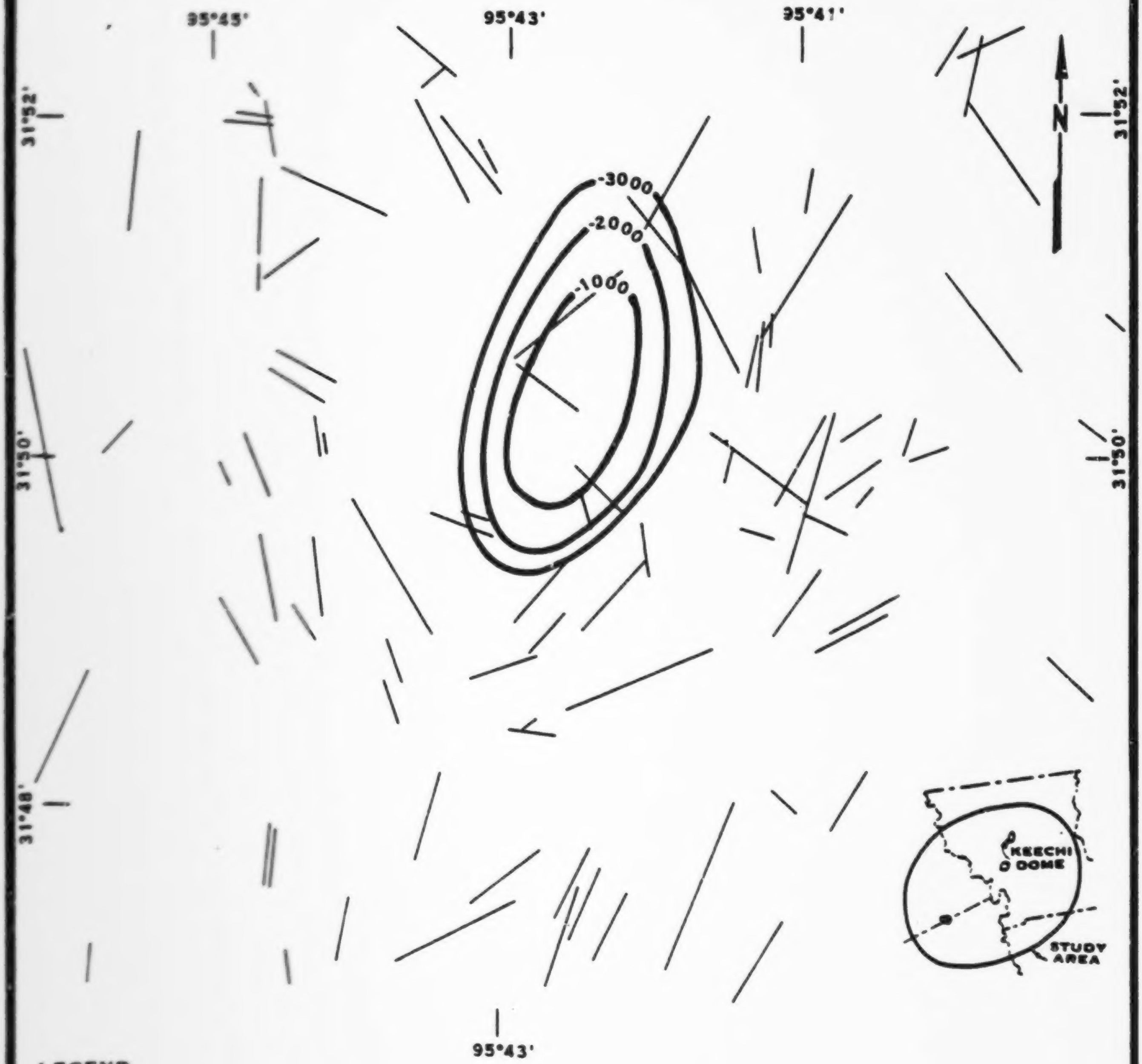

95°45'
95°43'
95°41'
31°52'
31°50'
31°48'
-3000
-2000
-1000
N
KEECHI DOME
STUDY AREA
95°43'

LEGEND

— -1000 — LINE OF EQUAL ELEVATION OF SALT. INTERVAL IS 1000 FEET. DATUM IS MEAN SEA LEVEL

———— LINEAMENTS

1 0 1 MI

1.5 0 1.5 KM

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY (1980)

PREPARED ____ DATE ____ REVISED ____ DATE ____ REVISED ____ DATE ____ APPROVED ____ DATE ____ T-1135-2	NATIONAL WASTE TERMINAL STORAGE PROGRAM GEOLOGIC EVALUATION GULF COAST SALT DOMES LAW ENGINEERING TESTING COMPANY MARIETTA GEORGIA	EAST TEXAS STUDY AREA KEECHI DOME AREA LINEAMENT MAP JOB NO. MV9600 FIGURE 7-20

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System. The growth of the dome has caused the beds nearest the dome to dip at such variably steep but undetermined angles (Figure 7-17) that the thicknesses cannot be accurately calculated.

The upper portion of the Travis Peak Formation of the Trinity Group is the oldest stratigraphic horizon to have been penetrated in the vicinity of the dome, and therefore it is the lowermost unit of the section described here (Figure 7-19). However, it is doubtful that descriptions of the older beds differ significantly from the generalized, regional lithology and thickness descriptions presented in Chapter 6. A lithologic description of the Louann Salt, which is believed to be the source of the domal salt, is presented in Section 6.2.2.1. Well logs, preliminary isochore maps (BEG, 1980), and seismic data in the vicinity of the dome are used to describe the geologic setting around the domal flanks. The lithology of the units is discussed in Chapter 6 and it is listed in Table 6-1.

7.2.2.2.1 Lower Cretaceous - The Lower Cretaceous consists of the Comanchean Series in the subsurface section of Keechi Dome and it is represented by (in ascending order) the Trinity, the Fredericksburg, and the Washita Groups.

The Trinity Group consists of the Travis Peak Formation, the Pettet Formation, the Glen Rose Subgroup (consisting of Lower Glen Rose, Ferry Lake, and Upper Glen Rose Formations) and the Paluxy Formation. The Lower Glen Rose Formation is divided into three members: the Pine Island Shale, the James Limestone, and the Rodessa which grades upward into the Ferry Lake Formation. Approximately 6 km (4 mi) south of the dome (Well 20-5), the thickness of the Trinity Group is at least 1,158 meters (3,800 ft). The Trinity Group conformably overlies the Cotton Valley Group.

The Fredericksburg Group is composed of two formations, the Goodland and Kiamichi, the total thickness of which (Well 20-5) is 171 meters (560 ft). The Fredericksburg Group is a transitional unit, lying conformably between the Washita Group above, and the Trinity Group below.

The Washita Group is composed of the Georgetown Subgroup and the Grayson, Buda, and Maness Formations. The thickness of the Washita Group is 396 meters (1,300 ft) (Well 20-5), and the unit is conformable with the overlying Woodbine Group.

7.2.2.2.2 Upper Cretaceous - The Upper Cretaceous (Gulfian Series) includes (from bottom to top) the Woodbine, Eagle Ford, Austin, Taylor, and Navarro Groups. The Taylor and Navarro Groups are exposed at the surface (Figure 7-17) and they are described in Section 7.2.2.1.

The Woodbine Group is undifferentiated in the subsurface. In Well 20-5, the group is 256 meters (840 ft) thick. A preliminary isochore map (BEG, 1980) for Keechi Dome indicates that the Woodbine beds pinch out upon the dome which, together with upturning of Woodbine beds at the dome, is illustrated in Figure 7-18.

The Eagle Ford Group is variously designated as group and formation in the subsurface in different localities. Well data south of the dome indicate a relatively constant thickness for the group. However, Figures 7-18 and 7-19 show that the Eagle Ford beds thin and are upturned toward the dome. The Eagle Ford Group is unconformable with the overlying Austin Group.

The Austin Group is divided into three formations (from bottom to top), the Ector, Middle Austin, and the Gober. The thickness of the Austin Group is 137 meters (450 ft) in Well 20-5. A preliminary isochore map around Keechi Dome and a cross section (Figure 7-18) (BEG, 1980) show a general trend of beds thinning toward the southeast in the study area and thinning at the dome. The Austin Group is conformably overlain by the Taylor Group.

7.2.2.2.3 Structure - The preliminary structural mapping of Upper Cretaceous and Lower Tertiary horizons, coupled with gravity data and published literature, suggest that Keechi Dome developed from a salt ridge, resulting in upwarping of overlying sediments. Uplift at Keechi appeared not to disturb the regional structural grain and it did not develop distinct rim synclines. Structural mapping by BEG, as well as by others (Ebanks, 1965; Lahee, 1933), indicated that the supradomal structure is fractured by a number of radial faults resulting from doming of the salt.

Structural interpretation of the Upper Cretaceous and Lower Tertiary horizons within an 8-km (5-mi) radius of Keechi indicates domal influence was confined to areas adjacent to the flanks. Similar influences are in evidence in the areas surrounding the structures of Concord Dome, 10 km (6 mi) north of Keechi Dome. Uplift at Keechi resulted in the surface exposure of Cretaceous beds off the southeast flank of the dome, surrounded by younger, Tertiary strata (Figure 7-17). Ebanks (1965) estimated approximately 1,280 meters (4,200 ft) of structural relief on the Lower Taylor in this general area. The uplift of the beds on the southeast flank of the dome is greater than at other flank positions, perhaps accounting for the asymetric geometry of Keechi Dome. Cross sections constructed across Keechi Dome (Figure 7-18) based on well and seismic data (Figure 7-19) show the steepness of the beds dipping away from the dome center. The substantial structural uplift of all beds adjacent to domal flanks and over the dome is associated with appreciable thinning of beds in the Upper Cretaceous and Lower Tertiary section. Interpretation of isochore data (Kreitler and others, 1980) indicates that the interval between the top of the Pecan Gap and the base of the Austin has thinned 122 meters (400 ft) from a maximum thickness of 457 meters (1,500 ft) west of the dome to 335 meters (1,100 ft) on the east (Figure 6-15). While thinning domeward is indicated for the entire Upper Cretaceous and Lower Tertiary section, it is more pronounced for the older beds. Faulting over the dome has influenced both structural relief and thinning of the section at Keechi.

Small arcuate troughs have been mapped (Kreitler and others, 1980; Ebanks, 1965) at Keechi, generally to the west of the dome, with other minor troughs to the north and south. The synclinal reentrants to the west, which generally correspond to areas of sediment accumulation, apparently represent local areas of salt withdrawal (Kreitler and others, 1980). The thick sediment accumulations in depressions to the north and south of the dome are more likely caused by a synclinal structure between Keechi and Concord Domes on the north, and Keechi and Palestine Domes on the south.

Because of the difficulty in interpreting driller's logs from early wells representing the major portion of subsurface control at the dome, faults at Keechi Dome have been mapped largely through surface studies and projected to depth. The faults are of two basic types: (1) major displacements trending northeast-southwest, roughly parallel to the longitudinal axis of Keechi Dome, and (2) minor branches of major faults. The major faults generally persist from the base of the Ector Formation to the surface and they are generally continuous across the top of the dome, with one overlying the overhang area of the dome on the southeast flank. Ebanks (1965) suggests that the generating mechanism for this fault zone is related to development of the overhang itself. He speculates that the major faulting at the dome formed a graben complex resulting from extension over the center of the dome. Branching faults, in the overall radial pattern characteristic of many, if not most, salt domes, resulted in a series of alternating, up-and-down fault blocks around the domal flanks (Figure 7-17). Irregular spacing of the sparse well data does not permit accurate dip measurements, but general estimates by Ebanks range between 45 and 75 degrees. He also speculates that faulting has apparently contributed to the oversteepened dips off the southsoutheast flank of the dome.

7.2.2.3 Dome Growth: Comparison of Keechi Dome with the Hainesville dome growth model (Loocke, 1978) indicates that Keechi, which shows no evidence of extrusion, has reached the truncation stage of development (Kreitler and others, 1980). The truncation stage is characterized by beds dipping away from the dome center as a result of upward movement of salt into the salt pillar. The absence of rim synclinal development at Keechi is attributed to the possibility that a major salt ridge supplied at least four salt structures, including Keechi, Palestine, Butler, and Concord. The evacuation of source material from a wide area resulted in a broad depression, which presumably accounts for the lack of localized depressions near the dome. Evidence suggests that Keechi is in an immature stage of dome development because beds are steeply inclined and thin away from the dome center, and no secondary rim synclines or collapse structures are found adjacent to the dome flanks.

7.2.3 MINERAL RESOURCES: There is no significant mineral resource extraction currently taking place at Keechi Dome; however, there is minor potential for future development of both petroleum and lignite (Murray, 1979) (Figure 7-21).

Petroleum exploration at Keechi Dome began in the early 1900's and has continued sporadically. The last test was in 1970, with the drilling of the Thrash and Lloyd No. 1 Link (LETCo

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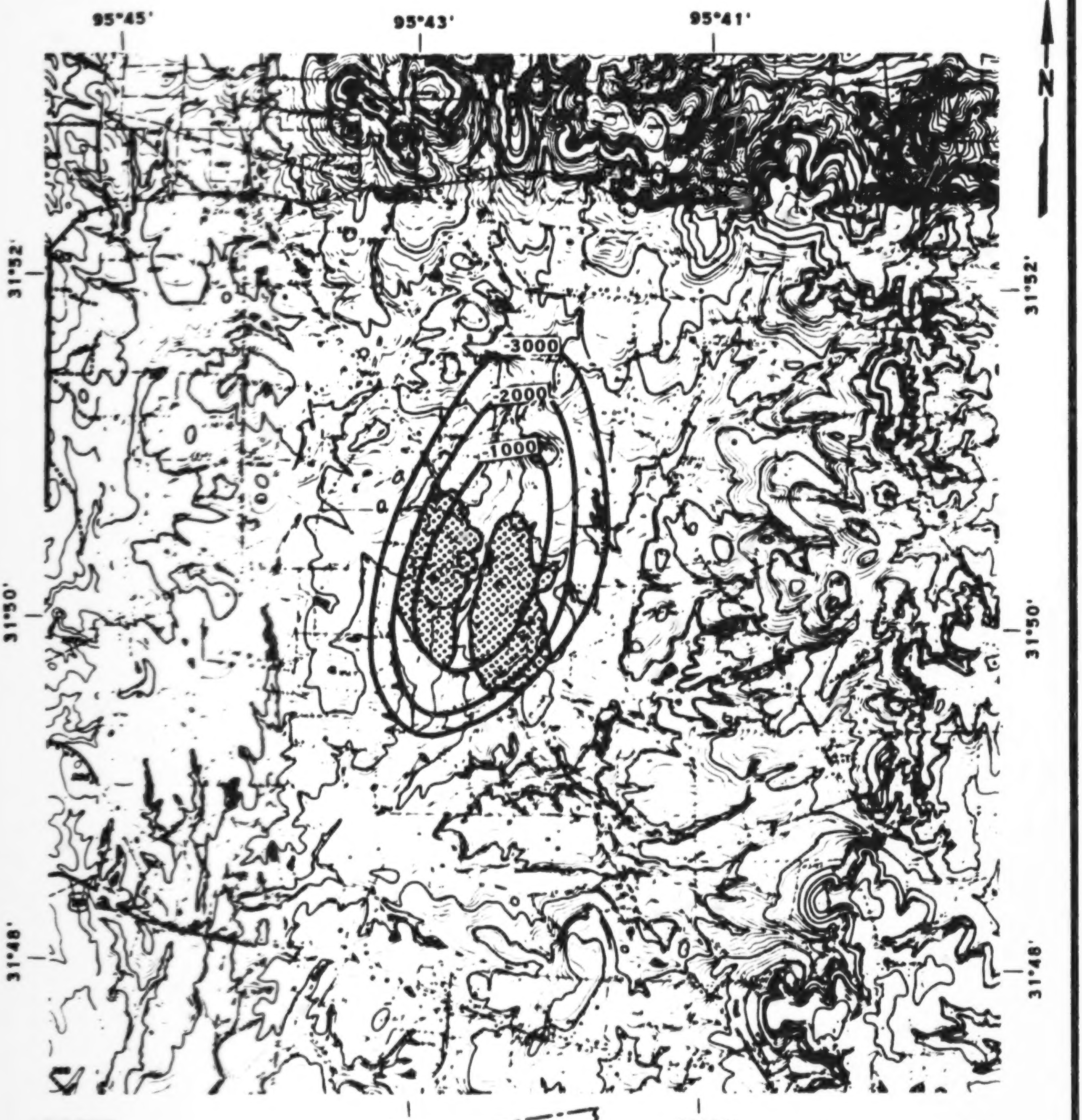

95°45'
95°43'
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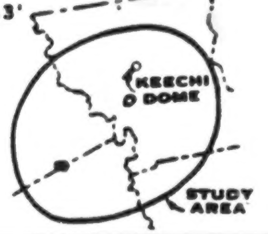
N
31°52'
31°52'
31°50'
31°50'
31°48'
31°48'
-3000
-2000
-1000
95°43'
95°41'

LEGEND

▨ POTENTIAL LIGNITE

— -1000 — LINE OF EQUAL ELEVATION OF SALT INTERVAL IS 1000 FEET.



KEECHI DOME
STUDY AREA

1 0 1 MI

1 0 1 KM

CONTOUR INTERVAL 20 FEET.
DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY
1: 24,000 QUADRANGLE.

PREPARED ____ DATE ____
REVISED ____ DATE ____
REVISED ____ DATE ____
APPROVED ____ DATE ____
T-1138-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

KEECHI DOME AREA
MINERAL RESOURCE
DEVELOPMENT

JOB NO. MV9600 FIGURE 7-21

BEST DOCUMENT AVAILABLE

K21-7) over the dome. Although exploration drilling in the domal area has reported some "good shows", no commercial production has been developed.

Lack of detailed subsurface data regarding steep dips at the domal flanks and complex faulting over the dome increases the difficulty of determining the exploration targets of past drilling efforts; however, the Woodbine Sands seem most likely to be the objective. The depth to the top of the Woodbine ranges from 152 meters (500 ft) above the dome to 1,524 meters (5,000 ft) off the flank. Characteristics for the Woodbine at Keechi, as determined from the depth interval 168 to 174 meters (550 to 571 ft) in Well K21-7, indicate an average porosity of 29 percent, and an average API gravity of 19 degrees for the crude samples recovered. The lack of development of petroleum resources at the dome is probably caused by the limited extent and scattered distribution of potential reservoir acreage as a result of complex radial faulting around the dome (Murray, 1979).

In addition to the possibility of free oil and gas resources at the dome, the potential for naturally occurring asphaltic sands is to be considered. According to Fisher (1965), traces of asphaltic sands occurred near and above the salt mass in association with the Queen City Formation, which surface geologic maps show is exposed over the east flank of the dome. Murray (1979) suggests that asphaltic sands may also be found in the Woodbine Formation at depth. The sands, when found, are impregnated with a heavy, tarry petroleum material accumulated in these near-surface deposits as a result of upward liquid petroleum migration under a combination of gas lift, capillary action, and hydraulic pressure through differential compaction and heat. At or near the ground surface, the light fraction of the liquid petroleum is lost through evaporation. It seems possible that the accumulation of asphaltic material at Keechi is the final stage of upward migration of petroleum from deeper reservoirs along the fault planes developed over the dome. Resource development of these asphaltic sands, if mineable, would probably be limited to a local market, possibly as a road metal binder.

The potential lignite resources at Keechi are in the upper portion of the Wilcox Group, inferred from surface geologic mapping and well data. Available driller's logs from wells at the dome indicate two lignite seams in the subsurface: an upper seam 0.3 to 0.9 meter (1 to 3 ft) thick over the domal crest and dipping off the west flank, and a lower seam 3 to 4 meters (11 to 14 ft) thick found only off the west flank. Overburden thicknesses over the dome range from 26 to 76 meters (86 to 250 ft). Future development of lignite at Keechi will be dependent on areal continuity and thickness of the seams, as well as on the applicability of in situ gasification equipment (Murray, 1979).

Although numerous mineral resources are noted by Murray (1979) to be present at Keechi, they are rated nonproductive, nonexploitable, nonuseable, or negligible to speculative. These resources include chalk, marl, limestone, glauconite, and kaolinitic clays.

7.3 PALESTINE DOME

Palestine Dome is centered in the western portion of Anderson County, approximately 10 km (6 mi) west of the center of the city of Palestine. According to the latest census figures, the population density in Anderson County is approximately 30 per square mile. The population in the west-central part of the county is concentrated within the city of Palestine and in nearby urban and rural areas. Suburban communities of Palestine are situated as close as 3 km (2 mi) from the center of the dome. The latest census indicates an estimated population of 32,500 in Palestine proper. There are about 25 separate property ownerships within a 3-km (2-mi) radius of the center of Palestine Dome.

The following sections consider the preliminary work completed to date in connection with describing the geometry of the salt, the near-dome geology, and mineral resources. Data gathering was discontinued at Palestine Dome by instructions from ONWI following BEG's recommendation that it be dropped as a potential repository site because of evidence of modern near-surface dissolution which could indicate a serious threat to containment integrity.

7.3.1 DOME GEOMETRY AND COMPOSITION: Regional gravity modeling of Palestine Dome characterized the structure as an oval in plan view (Figure 7-22) with the long axis oriented north-northeasterly, and mound-like in longitudinal profile (Figure 7-23). Regional gravity and well data indicate that the dome overlies a north-northeast-trending salt ridge along with Keechi, Butler,

[redacted]

and Concord Domes (Figure 6-9). An overhang has been mapped on the eastern flank at Palestine Dome. Calculations from the gravity model (Figure 7-22) indicate that the dome encompasses a total area of 677, 786, and 924 hectares (1,672, 1,943 and 2,284 acres) at -610, -762, and -914 meters (-2,000, -2,500 and -3,000 ft).

Well data at Palestine Dome are inadequate to describe in detail the lithologic character and relationships of the caprock and the salt (Table 7-3). Approximately 20 wells were drilled in the early part of the century for brine production to depths that could have penetrated salt or caprock; however, no lithologic information about the rocks penetrated was recorded (Powers, 1926). Published reports state that these brine wells were less than 152 meters (500 ft) deep and that the shallowest depths at which caprock and salt were encountered at the Palestine Dome were approximately 15 to 37 meters (50 to 120 ft) below the surface. Records of five oil and gas wells in the vicinity of the dome offer no stratigraphic information regarding the shallow formations. The data from the Texaco No. 1 Davey (LETCo 20-15) well (Figure 7-22) does indicate the possibility of a bulge on the dome in the depth interval 1,646 to 2,803 meters (5,400 to 9,197 ft) where the base of the caprock is interpreted to be at approximately -1,067 meters (-3,500 ft) MSL. The thickness of caprock at the dome is reported to be a maximum of 15 meters (50 ft). Anderson and others (1973) describe the caprock as limestone. The composition of the salt at Palestine is assumed to be similar to other East Texas salt domes, i.e., 90-95 percent pure crystalline halite, with anhydrite as the major impurity (Section 7.1.1).

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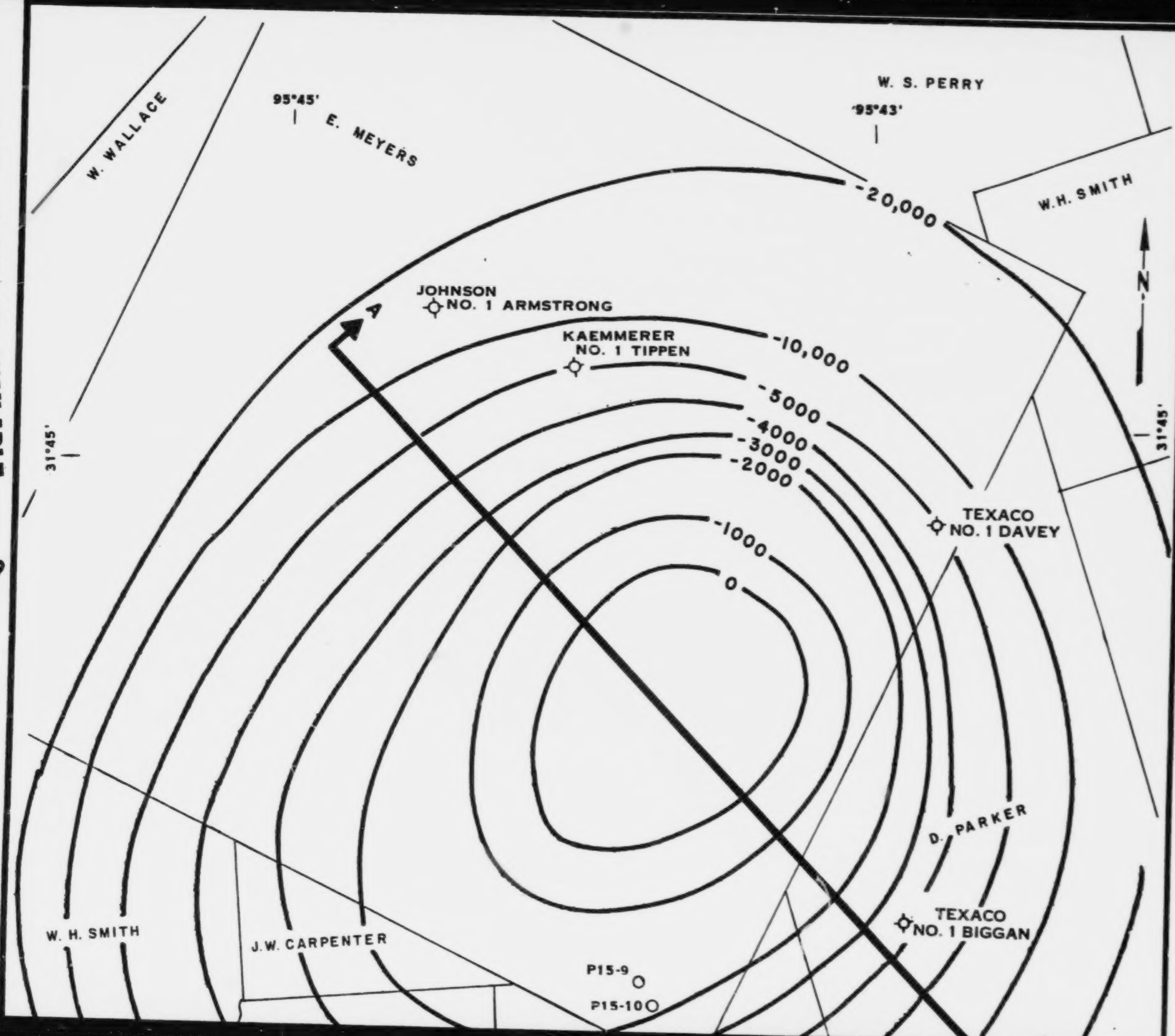
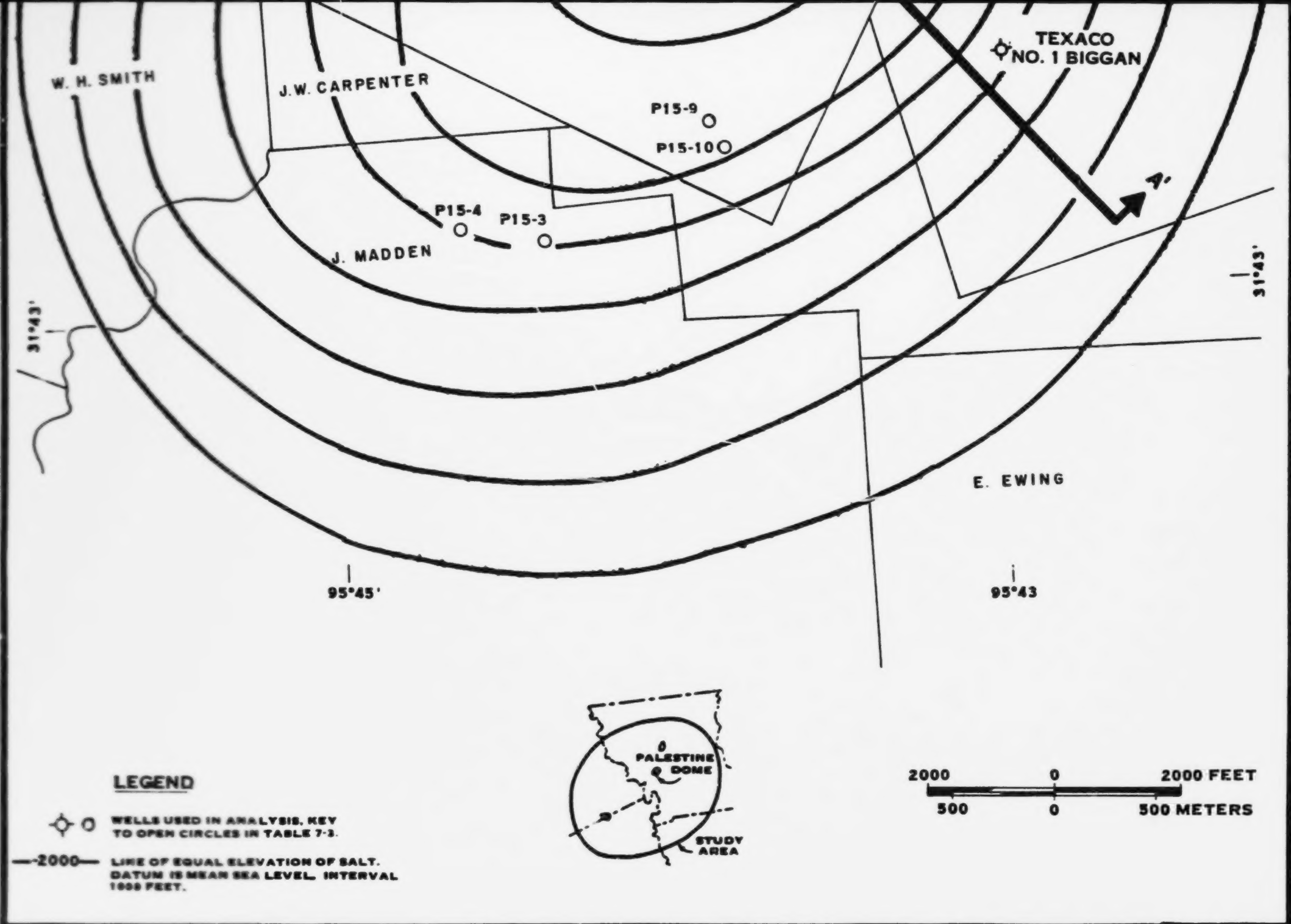

W. WALLACE
95°45'
E. MEYERS
W. S. PERRY
95°43'
W.H. SMITH
N
-20,000
JOHNSON
NO. 1 ARMSTRONG
A
KAEMMERER
NO. 1 TIPPEN
-10,000
-5000
-4000
-3000
-2000
31°45'
31°45'
TEXACO
NO. 1 DAVEY
-1000
0
D. PARKER
TEXACO
NO. 1 BIGGAN
W. H. SMITH
J.W. CARPENTER
P15-9
P15-10

BEST

BEST DOCUMENT AVAILABLE

169A


W. H. SMITH
J.W. CARPENTER
TEXACO NO. 1 BIGGAN
P15-9
P15-10
A'
P15-4
P15-3
J. MADDEN
31°43'
31°43'
E. EWING
95°45'
95°43
PALESTINE DOME
STUDY AREA
2000
0
2000 FEET
500
0
500 METERS

LEGEND

WELLS USED IN ANALYSIS, KEY TO OPEN CIRCLES IN TABLE 7-3.

—2000— LINE OF EQUAL ELEVATION OF SALT. DATUM IS MEAN SEA LEVEL. INTERVAL 1000 FEET.

PREPARED ____ DATE 8/05/80
REVISED ____ DATE 11/17/81
REVISED ____ DATE ____
APPROVED ____ DATE 8/15/80

T-1140-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

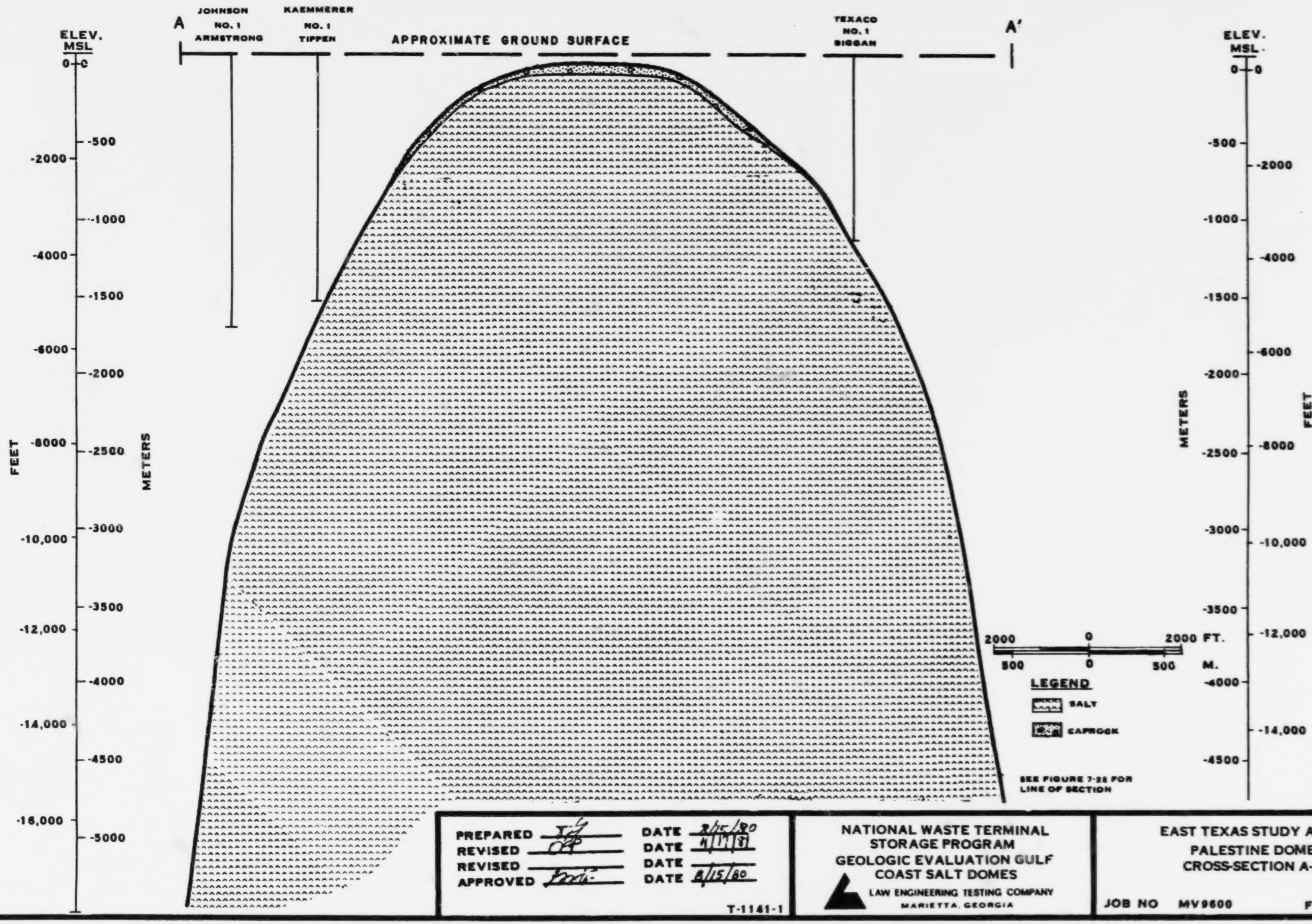
LAW ENGINEERING TESTING COMPANY
MARIETTA . GEORGIA

EAST TEXAS STUDY AREA
PALESTINE DOME
SALT STRUCTURE AND WELL LOCATION MAP

JOB NO. MV9600

FIGURE 7-22

FIGURE 7-22


A
JOHNSON NO. 1 ARMSTRONG
KAEMMERER NO. 1 TIPPEN
APPROXIMATE GROUND SURFACE
TEXACO NO. 1 BIGGAN
A'
ELEV. MSL
FEET
METERS
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-2000
-4000
-6000
-8000
-10,000
-12,000
-14,000
-16,000
2000 0 2000 FT.
500 0 500 M.
LEGEND
SALT
CAPROCK
SEE FIGURE 7-22 FOR LINE OF SECTION

PREPARED I.G. DATE 2/15/80
REVISED OP DATE 4/17/81
REVISED DATE
APPROVED DATE 8/15/80

T-1141-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
PALESTINE DOME
CROSS-SECTION A-A'

JOB NO MV9600

FIGURE 7-23

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

TABLE 7-3

PALESTINE DOME BOREHOLE DATA SUMMARY

WELL NAME	LETCo WELL No.	LOCATION*	ELEV. (MSL) G.L.(FT)	TOTAL DEPTH (FT)	LOGS+ RUN	CASING DIA (OD) DEPTH	GROUTING	CASING SEAT DEPTH (FT)	ABANDONMENT PROCEDURE	ELEV. (MSL) TOP CAPROCK/ THICKNESS PENETRATED (FT)	ELEV. (MSL) TOP SALT/ THICKNESS PENETRATED (FT)	SOURCE	REMARKS
Sun #2, Bowers & Maier	P15-10	E. G. Meyer Surv. 1300' FSEL & 970 FSWL of surv.	310'	2041'	Drlrs log, sample log	12¼" - 123'	No Info.	123'	No Info.	1819/-1509 52'	1871/-1561	TX Well Log Serv., TBEG	Drilled in 1930. Caprock could be thicker. D & A
Sun #1, Bowers & Maier	P15-9	E. G. Meyer Surv. 1680' FSEL & 1000' FSWL of surv.	310'	1656'	Drlrs log, sample log	12¼" - 296'	No Info.	296'	No Info.	1656/-1346 No thickness data.	No Info.	TX Well Log Serv., TBEG	Drilled in 1930's. D & A
Texas Co. #1 Wright	P15-3	Jas. Madden Surv. 660' out of middle NE corner.	DF - 305' KB - 308'	3190'	Elec. log	13 3/8" - 282' 9 5/8" - 800'	No Info.	282' 800'	No Info.	Caprock not reached	salt not reached.	Comp. card, log.	Drilled in 1948. D & A
Texas Co. #2 Wright	P15-4	Jas. Madden Surv. A-39 1735 FNL & 2300'F middle of E/L	DF - 301'	3882'	Elec. log	13 3/8" - 262' 9 5/8" -1027'	No Info.	262' 1027'	No Info.	No Info.	-3539	Comp. card, log.	Drilled in 1948. D & A

*FNL, FWL, FSEL, etc.: F=from; N, W, SE, etc. = direction; L = Line.
+Geophysical log. This is a continuous log of some physical property, such as resistivity, density, temperature, of rock material obtained by lowering an instrument into a borehole.

7.3.2 NEAR-DOME GEOLOGY: This section includes a discussion of surface and subsurface geology of the Palestine Dome area.

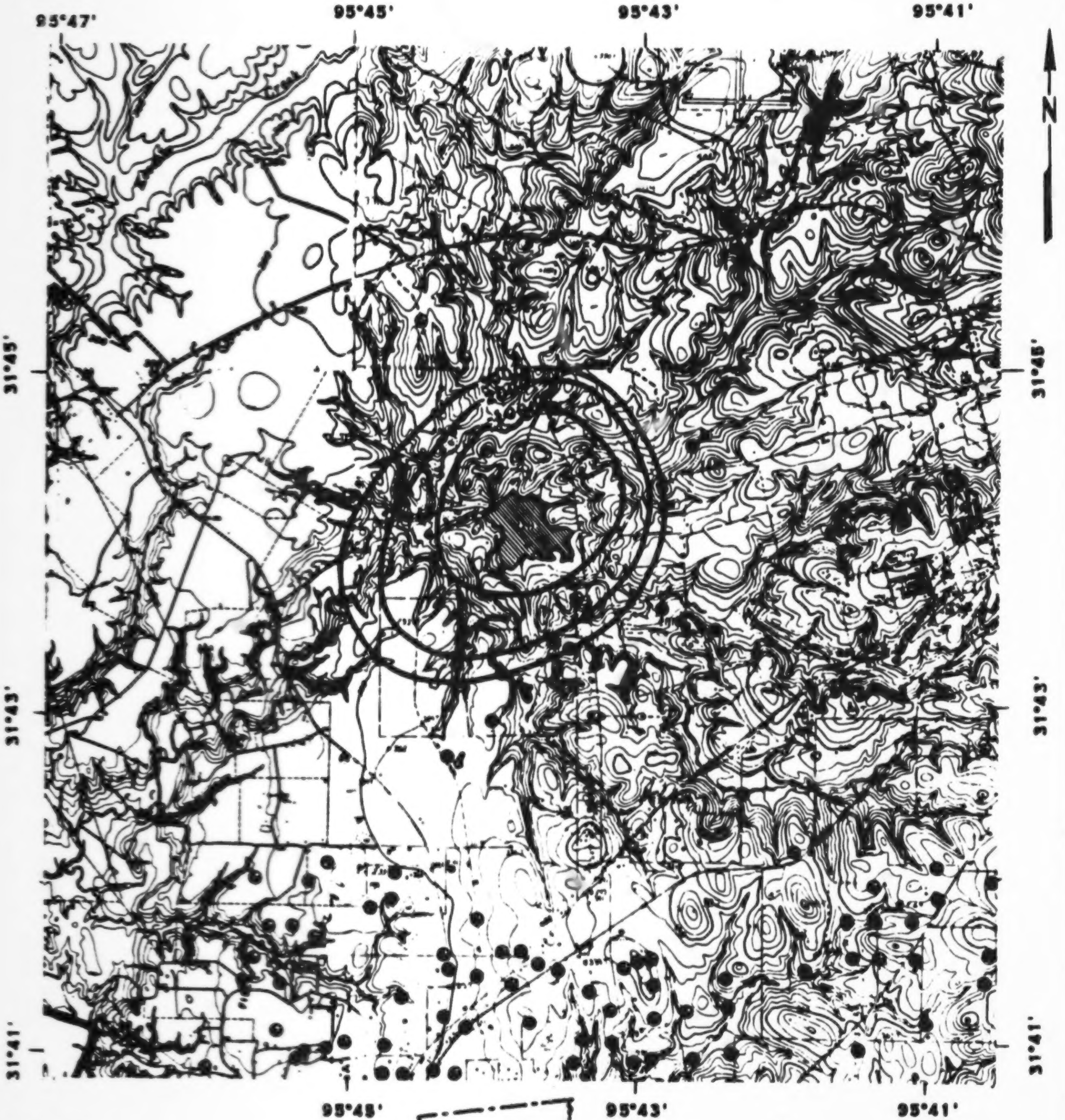
7.3.2.1 Surface Geology: The following paragraphs describe the physiographic characteristics, outcrop patterns, and structural features observed at the surface above Palestine Dome.

7.3.2.1.1 Physiography - The Palestine Dome area, lying wholly within the Rolling Hills and Prairie Physiographic Subprovince, displays surface topography, climate, vegetation, and land use typical of the East Texas Study Area (Section 6.2.1).

The gently undulating topography (Figure 7-24) within the subprovince is caused largely by differential erosion of relatively soft strata alternating with more resistant beds. Gulfward-dipping beds characterize the general physiographic nature of the supradomal area. The domal area has been strongly influenced physiographically by the erosional and depositonal activity of tributaries of the nearby Trinity River. Much of the section exposed at the surface in the immediate vicinity of the dome has been described as relatively flat-lying Quaternary terrace material deposited in older stream channels and then partly eroded (Hightower, 1958).

Palestine Dome lies within the drainage basin of the Trinity River, and much of the domal area is overlain by relatively flat-lying alluvial terrace deposits (Figure 7-24). The supradomal area is topographically low, partially surrounded by a series of low, discontinuous ridges or cuestas. Duggey's Lake, a saline 2

AF 12338A


95°47'
95°45'
95°43'
95°41'
N
31°45'
31°43'
31°41'
95°45'
95°43'
95°41'

PALESTINE DOME
STUDY AREA

1 0 1 MI

1 0 1 KM

LEGEND

●	OIL OR GAS WELL
—·1000—	LINE OF EQUAL ELEVATION OF SALT. INTERVAL IS 1000 FEET.

CONTOUR INTERVAL 20 FEET.

DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY 1: 24,000 QUADRANGLE.

PREPARED [illegible] DATE [illegible] REVISED [illegible] DATE 4/11/21 REVISED ____ DATE ____ APPROVED [illegible] DATE [illegible] T-1468-1	NATIONAL WASTE TERMINAL STORAGE PROGRAM GEOLOGIC EVALUATION GULF COAST SALT DOMES LAW ENGINEERING TESTING COMPANY MARIETTA . GEORGIA	EAST TEXAS STUDY AREA PALESTINE DOME AREA TOPOGRAPHIC MAP AND DATA UTILIZED IN ANALYSIS JOB NO. MV9600 FIGURE 7-24

BEST DOCUMENT AVAILABLE

[redacted]

to 4 meters (6 to 12 ft) deep, occupies a central depression over the dome, suggesting the possibility of collapse* above the salt crest (Figure 7-25). Several old brine wells associated with recent sinks also suggest the existence of collapse structures above the dome. Near the inner margin of the surrounding hills are the two major drainage courses of the area, Town Creek on the south and Wolfe Creek on the north (Figure 7-25). These two creeks have developed an annular drainage pattern and they receive smaller streams which drain the inner portion of the supradomal area. The smaller tributaries follow a radial pattern, suggesting fault control.

Elevations range from about 73 meters (240 ft) at Duggey's Lake to more than 122 meters (400 ft) along the higher land on the nearby surrounding ridges. The largest river terrace in the area attains a maximum elevation of about 104 meters (340 ft). Modern erosion has reduced the terrace to a 91-meter (300-ft) elevation over much of its surface around the dome, with a gentle slope toward the Trinity River. A small area northeast of Duggey's Lake has been mapped as an alluvial terrace deposit (Hightower, 1958)**. The maximum elevation on this terrace is 116 meters (380 ft) and, like the larger terrace, it slopes gently toward the river.

---

*The collapse of bedding above a salt dome may be caused by the removal of structural support because of dissolution or development of a graben structure from extension stress developed within arching beds.

**BEG is reevaluating prior work (Hightower, 1958) which mapped sediments on the west and southwestern portion of Palestine Dome as Quaternary terraces.

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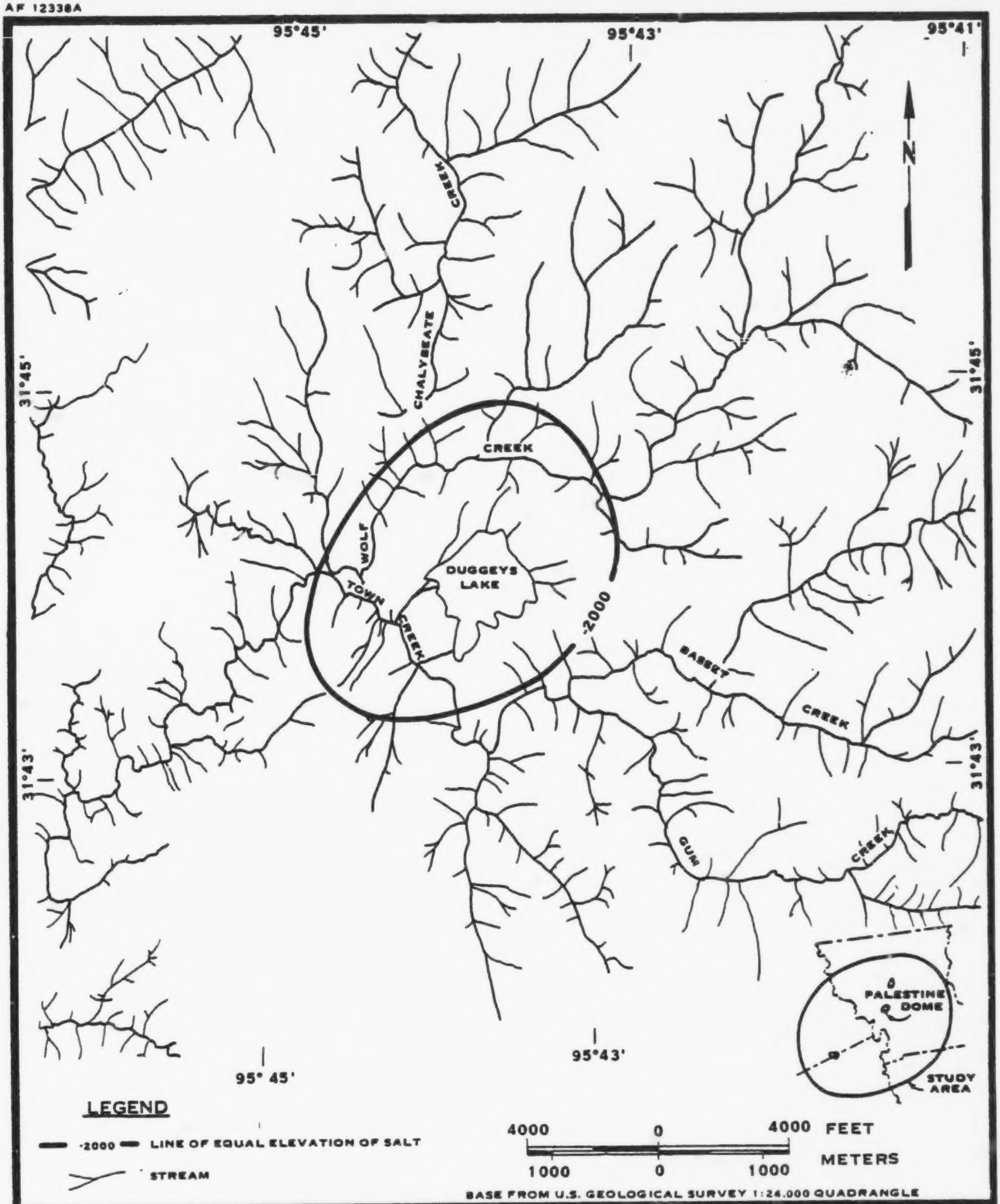

95°45'
95°43'
95°41'
N
31°45'
31°43'
CHALYBEATE
CREEK
WOLF
CREEK
TOWN
CREEK
DUGGEYS LAKE
-2000
BASSET
CREEK
GUM
CREEK
PALESTINE DOME
STUDY AREA
LEGEND
-2000 LINE OF EQUAL ELEVATION OF SALT
STREAM
4000 0 4000 FEET
1000 0 1000 METERS
BASE FROM U.S. GEOLOGICAL SURVEY 1:24,000 QUADRANGLE

PREPARED [illegible] DATE [illegible]
REVISED [illegible] DATE [illegible]
REVISED _____ DATE _____
APPROVED [illegible] DATE [illegible]
T-1145-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

PALESTINE DOME AREA
DRAINAGE NETWORK

JOB NO. MV9600 FIGURE 7-25

[redacted]

BEST DOCUMENT AVAILABLE

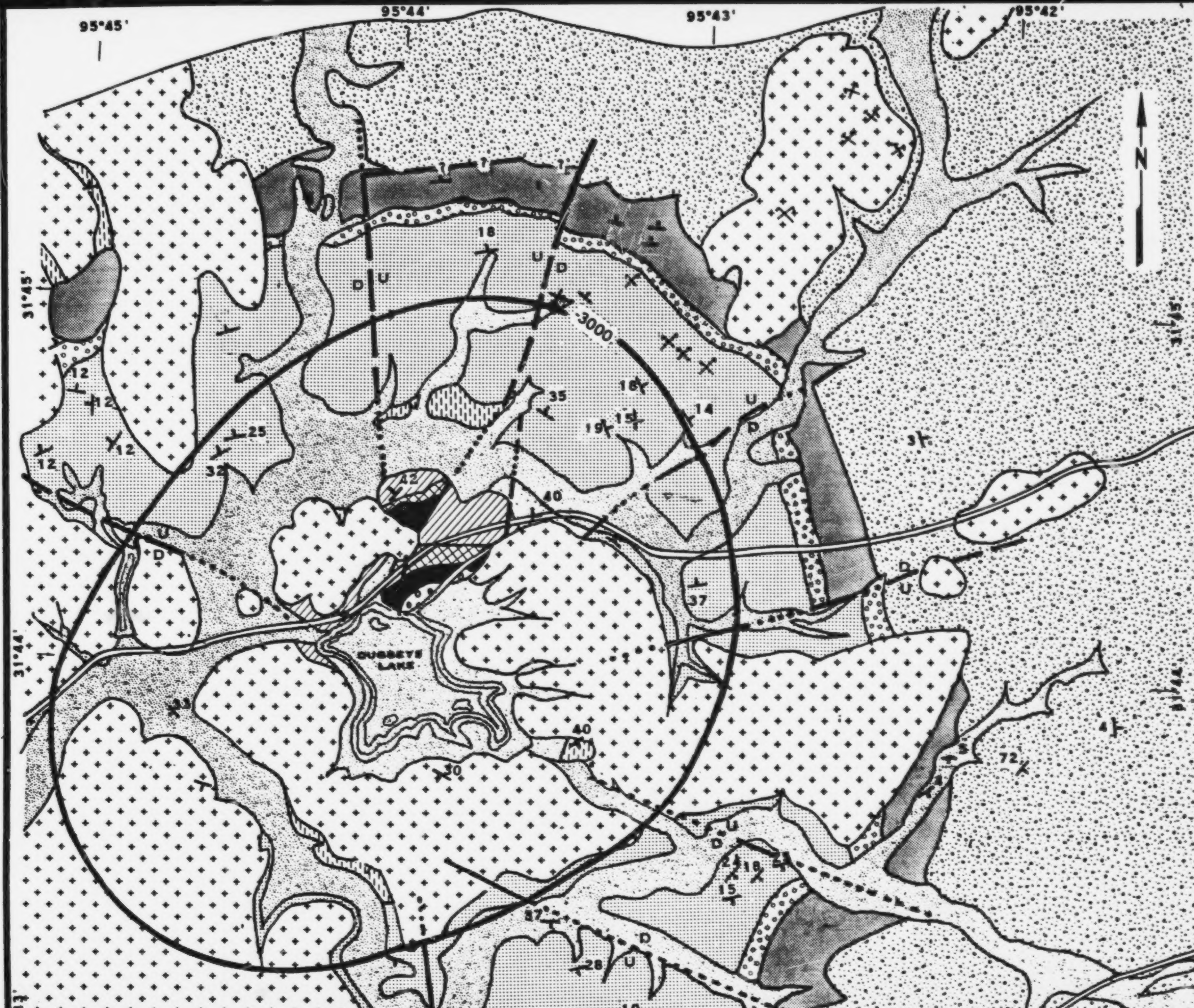
7.3.2.1.2 Outcropping Geologic Units - The exposed rocks within the domal area are Cretaceous, Tertiary, and Quaternary in age (Figure 7-26). The Cretaceous beds are represented by the Comanchean Series and the Gulfian Series. Stratigraphic units of the Tertiary System are also exposed and they include sediments of Paleocene, Eocene, and Pleistocene age.

The Comanchean Series of the Cretaceous System is represented at the surface by the Buda Formation. The Buda, a formation of the Washita Group, is the oldest exposed unit (Hightower, 1958). At the surface of the dome the Buda is approximately 8 meters (25 ft) thick; but in the Tidewater No. 4 Evans (LETCo 28-25) well, which was drilled 8 km (5 mi) southwest of the dome, the thickness is 40 meters (130 ft) at a depth of 1,826 meters (5,990 ft) [-1,735 meters (-5,692 ft) MSL]. In normal sequence the Maness overlies the Buda, as it does in Well 28-25, where the thickness is 32 meters (105 ft). The Maness is not known to be exposed at the dome; if actually missing, the gap may indicate an erosional unconformity formed during a period of emergence prior to the deposition of the Gulfian Series.

The base of the Gulfian Series is represented by the Woodbine Group, which unconformably overlies the Buda in the outcrop. The portion of the Woodbine Group that is exposed over the dome is characterized by weathered, massive to poorly bedded, fine-grain sandstone. The Woodbine was deposited in a lagoonal-deltaic environment. The limited thickness of this unit at the dome [approximately 11 meters (35 ft)] is considered to be structurally significant because in Well 28-25 it is 244 meters (800

BEST DOCUMENT AVAILABLE

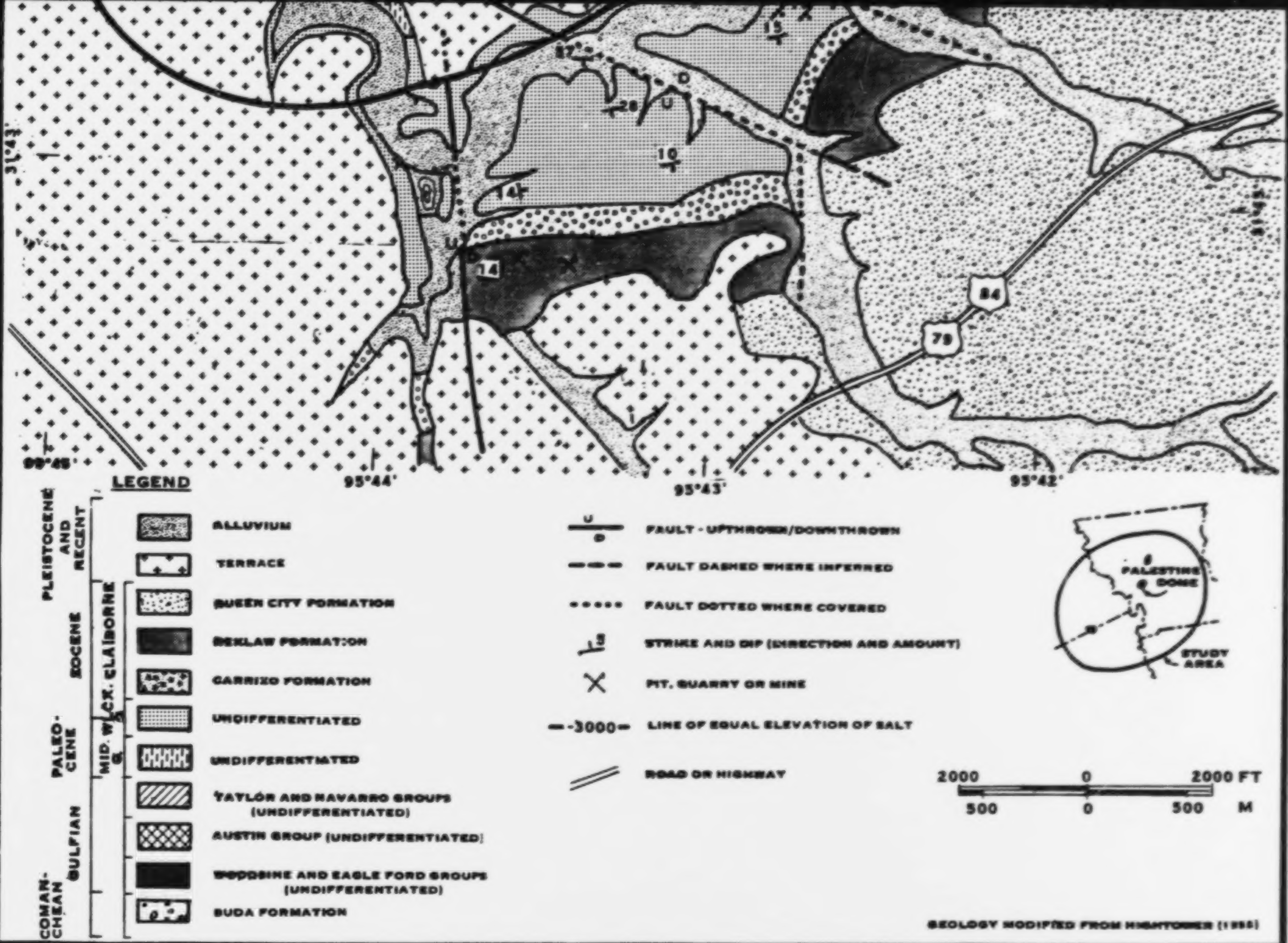
177


95°45'
95°44'
95°43'
95°42'
31°45'
31°44'
31°43'
N
-3000
DUGGEYS LAKE
U
D
18
12
25
32
35
18
15
19
14
42
40
37
3
4
33
30
40
72
5
24
18
23
15
27
28
10

BEST DOCUMENT AVAILABLE

17.74

FIGURE 7-26


31°43'
95°45'
95°44'
95°43'
95°42'
31°43'
15
87°
28
10
14
14
U
D
84
79
LEGEND
PLEISTOCENE AND RECENT
EOCENE
PALEOCENE
GULFIAN
COMANCHEAN
CLAIBORNE
MID. W. CX.
ALLUVIUM
TERRACE
QUEEN CITY FORMATION
REKLAW FORMATION
CARRIZO FORMATION
UNDIFFERENTIATED
UNDIFFERENTIATED
TAYLOR AND NAVARRO GROUPS (UNDIFFERENTIATED)
AUSTIN GROUP (UNDIFFERENTIATED)
WOODBINE AND EAGLE FORD GROUPS (UNDIFFERENTIATED)
BUDA FORMATION
FAULT - UPTHROWN/DOWNTHROWN
FAULT DASHED WHERE INFERRED
FAULT DOTTED WHERE COVERED
STRIKE AND DIP (DIRECTION AND AMOUNT)
PIT, QUARRY OR MINE
-3000 LINE OF EQUAL ELEVATION OF SALT
ROAD OR HIGHWAY
2000 0 2000 FT
500 0 500 M
PALESTINE DOME
STUDY AREA

GEOLOGY MODIFIED FROM HIGHTOWER (1958)

PREPARED ____ DATE 8/15/80
REVISED ____ DATE 11/17/81
REVISED ____ DATE ____
APPROVED ____ DATE 8/18/80

T-1147-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
PALESTINE DOME AREA

GEOLOGIC MAP

JOB NO. MV9600

FIGURE 7-26

ft) thick. Two alternative explanations have been postulated (Hightower, 1958) to explain the difference: (1) the thin section is not typical but localized, representing upthrown fault blocks that have been partially eroded, or (2) deposition of the Woodbine occurred simultaneously with supradomal faulting and domal uplift, resulting in substantial stratigraphic thinning of the entire group throughout the supradomal area. Preliminary isochore mapping (Kreitler and others, 1980), which shows a general thinning of sediments in the Woodbine toward the dome, tends to support the thesis of deposition contemporaneous with structural adjustment.

The Eagle Ford Group overlies the Woodbine Group and is described in the outcrop as soft to firm, laminated, slightly glauconitic, sandy and silty shale in the lower portion, becoming more calcareous and sandy with thin beds of fine-grain sand in the upper portion. The Eagle Ford is exposed in at least two locations over the dome because of faulting where the thickness is 38 meters (125 ft). The thickness of the Eagle Ford in Well 28-25 is 70 meters (230 ft). Thinning of the unit toward the dome is confirmed by examination of the Eagle Ford thicknesses in other nearby wells (Figure 7-28). The Eagle Ford was deposited under generally shallow neritic conditions.

The only formation of the Austin Group present over the dome is the Ector, which at the surface is a fossiliferous, chalky limestone. This upper unit is prominent on the surface. It is very white, resistant to weathering, and 9 to 61 meters (30 to 200 ft) thick. Around the flanks of the dome, according to preliminary isochore mapping (BEG, 1980), the Austin is approximately 122 meters (400 ft) thick. The Austin Group in the dome study area tends to thin toward the southeast. Thinning of this unit over Palestine Dome (Figure 7-28) could be caused by contemporaneous faulting (Hightower, 1958). (See Figure 7-27 for location of cross section.) The depositional environments of the Austin Group ranged from marine carbonate shelf at the base, through deep neritic, to coastal plain deposits in its upper portion.

The Taylor Group, undifferentiated in the outcrop, is massive to poorly bedded, fossiliferous, calcareous marl and clay containing some fine-grain sand, sandy limestone, and sandy marl. It varies from 183 to 274 meters (600 to 900 ft) thick at the dome. The usual thickness encountered elsewhere in the basin is 366 to 457 meters (1,200 to 1,500 ft). Preliminary isochore maps (BEG, 1980) and Figure 7-28 show extensive thinning of the Lower Taylor Formation and a slight thinning of the Pecan Gap and Upper Taylor Formations toward the dome. The Taylor Group includes sediment of various marine depositional environments including neritic, carbonate shelves and littoral, strandline deposits.

The Navarro Group consists of three formations - the Lower Navarro, Nacatoch, and Upper Navarro.* At the outcrop near the dome, the Lower Navarro is calcareous shale and marl. The Nacatoch is a marl interbedded with sandy clay. The Upper Navarro consists of sandstone and siltstone with some clays. The thickness of the entire group is about 76 meters (250 ft) at the dome and approximately 91 meters (300 ft) elsewhere in the basin. Marine depositional environments during the time of Navarro deposition were deep to shallow neritic. Hightower (1958) mapped the Navarro and Taylor Groups as an undifferentiated sequence because of the poor condition of the outcrops and the indistinguishable soils.

---

*BEG divides the Upper Navarro into a lower marl and an upper clay zone.

The Midway Group of the Paleocene Series is exposed over Palestine Dome. The Midway Group is described as a sequence of argillaceous shale beds, laminated to poorly bedded, micaceous, with some thinly-bedded ferruginous sand layers in the upper portion. Soils of the Midway Group are typically silty sands underlain by sandy clays. From surface exposures over the dome the Midway has been calculated to be about 198 meters (650 ft) thick, whereas it is normally about 244 meters (800 ft) thick in other areas of the basin (Hightower, 1958).

The beds of the Eocene Series exposed in the Palestine Dome area include members of the Wilcox* and Claiborne Groups. The Wilcox Group is typically variable in lithologic content, consisting of laterally discontinuous deposits of predominantly fluvial-deltaic facies. Along the northern and western margins of the Northeast Texas Embayment the Wilcox is subdivided; however, at the domes, because of the limited section exposed, the group is undifferentiated. The Wilcox in the domal area is a heterogeneous sequence of cross-bedded to plane-bedded, silty

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*The lowermost portion of the Wilcox Group is late Paleocene; the upper part is early Eocene.

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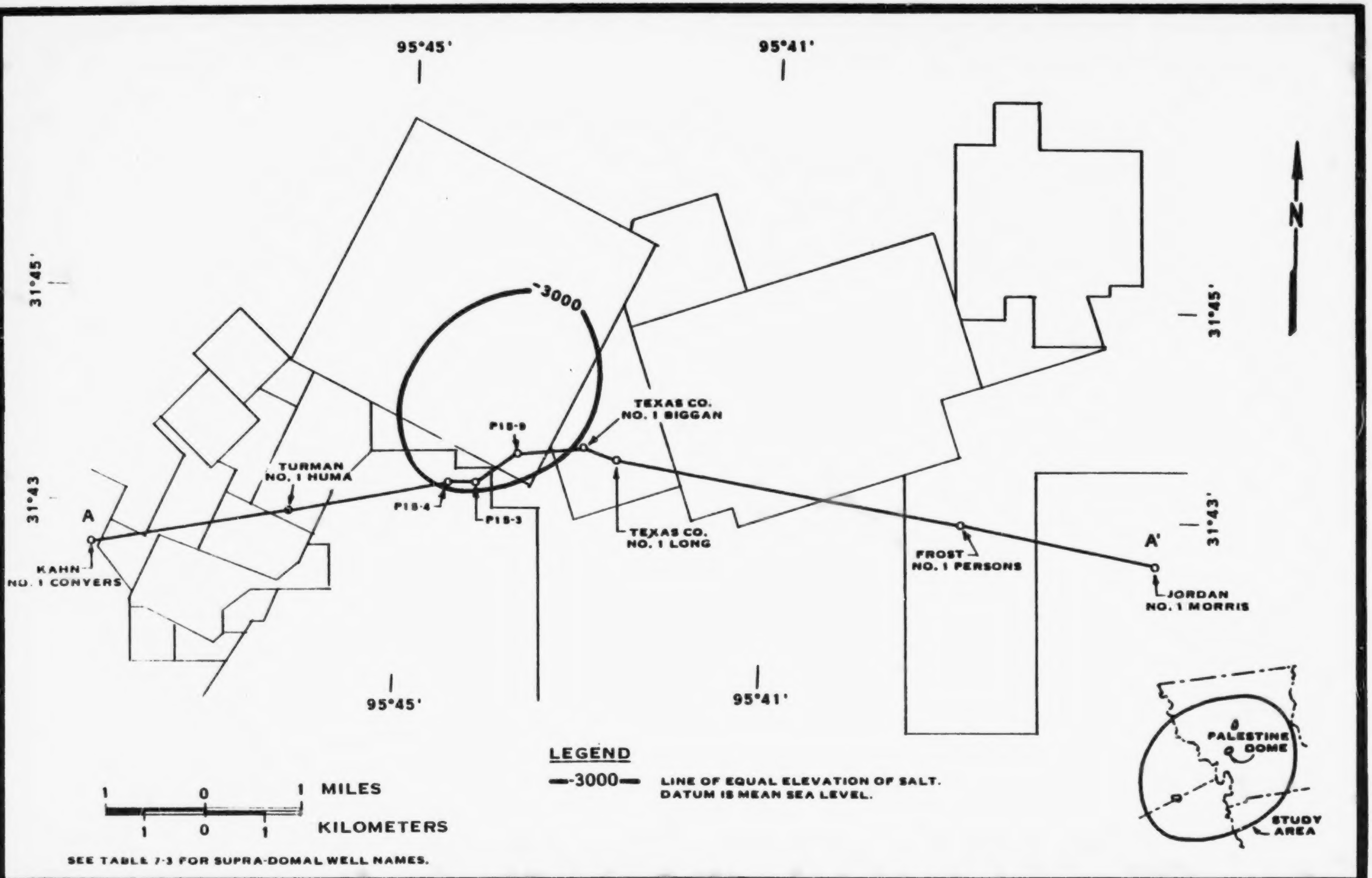
95°45'
95°41'
31°45'
31°45'
31°43'
31°43'
N
-3000
TEXAS CO.
NO. 1 BIGGAN
P15-9
TURMAN
NO. 1 HUMA
A
P15-4
P15-3
TEXAS CO.
NO. 1 LONG
KAHN
NO. 1 CONYERS
FROST
NO. 1 PERSONS
A'
JORDAN
NO. 1 MORRIS
95°45'
95°41'
LEGEND
-3000 LINE OF EQUAL ELEVATION OF SALT. DATUM IS MEAN SEA LEVEL.
1 0 1 MILES
1 0 1 KILOMETERS
PALESTINE DOME
STUDY AREA

SEE TABLE 7-3 FOR SUPRA-DOMAL WELL NAMES.

PREPARED	TH	DATE	[illegible]
REVISED	[illegible]	DATE	11/17/81
REVISED		DATE	
APPROVED	[illegible]	DATE	6/12/81

T-1461-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
PALESTINE DOME AREA WEST-EAST CROSS-SECTION LOCATION MAP

JOB NO. MV9600

FIGURE 7-27

FIGURE 7-27

BEST DOCUMENT AVAILABLE

[redacted]

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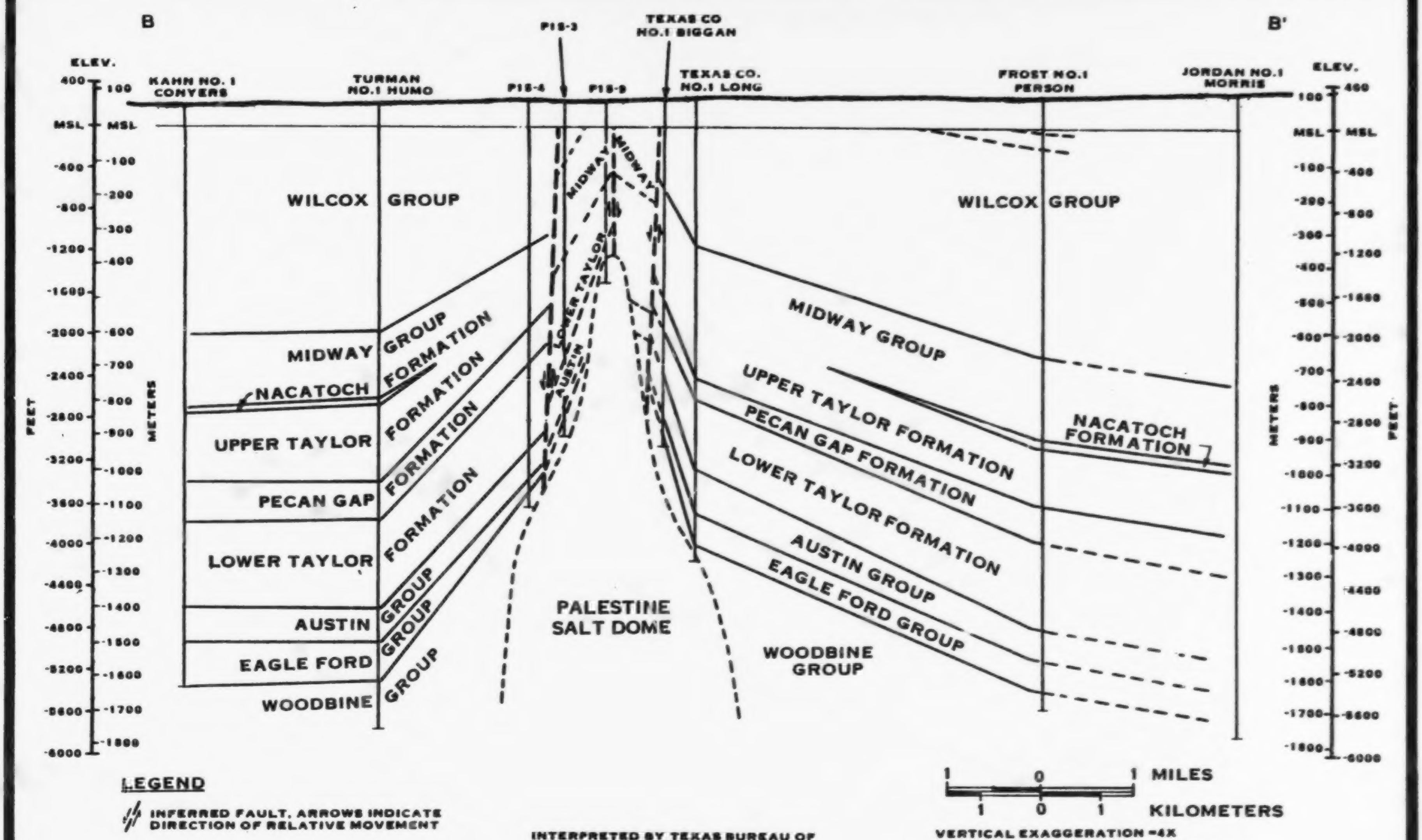
B
B'
P1S-3
TEXAS CO
NO.1 BIGGAN
ELEV.
400
100
KAHN NO. 1
CONYERS
TURMAN
NO.1 HUMO
P1S-4
P1S-9
TEXAS CO.
NO.1 LONG
FROST NO.1
PERSON
JORDAN NO.1
MORRIS
MSL
-100
-200
-300
-400
-600
-700
-800
-900
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-400
-800
-1200
-1600
-2000
-2400
-2800
-3200
-3600
-4000
-4400
-4800
-5200
-5600
-6000
FEET
METERS
WILCOX GROUP
MIDWAY GROUP
NACATOCH FORMATION
UPPER TAYLOR FORMATION
PECAN GAP FORMATION
LOWER TAYLOR FORMATION
AUSTIN GROUP
EAGLE FORD GROUP
WOODBINE GROUP
MIDWAY
MIDWAY
LOWER TAYLOR
AUSTIN
PALESTINE SALT DOME
1
0
1
MILES
1
0
1
KILOMETERS

LEGEND

INFERRED FAULT, ARROWS INDICATE DIRECTION OF RELATIVE MOVEMENT

INTERPRETED BY TEXAS BUREAU OF ECONOMIC GEOLOGY, 1979

VERTICAL EXAGGERATION =4X

SEE FIGURE 7-30 FOR LINE OF SECTION

PREPARED JH DATE 9/15/80
REVISED DFP DATE 11/7/81
REVISED DATE
APPROVED DATE 8/15/80
T-1040-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
WEST - EAST CROSS SECTION
OVER PALESTINE DOME

JOB NO. MV9600

FIGURE 7-28

FIGURE 7-28

clays and silty sands, siltstones, and some thinly-bedded lignite zones. Some portions of the Wilcox contain layers of ironstone concretions and small amounts of glauconite. Wilcox soils are commonly loose sands underlain by clays. The Wilcox Group, about 366 meters (1,200 ft) thick, is the thickest unit exposed. Though no rim syncline is evident, a preliminary isochore map (BEG, 1980) indicates thickening toward the dome, as well as a general, regional trend of thickening toward the southeast.

The Claiborne Group is represented by the Carrizo, Reklaw, and Queen City Formations. The Carrizo consists of two distinct lithologic portions. The lower portion consists of fine-grain, very porous, clean sand with traces of carbonaceous material. Bedding is graded, becoming increasingly lenticular with an associated decrease in grain size upward in this part of the section. The upper portion of the Carrizo is composed of a silty clay grading laterally into a silty sand. The Carrizo weathers to a loose, sandy soil. The thickness of the Carrizo Formation varies from 6 meters (20 ft) around the dome to 34 meters (110 ft) elsewhere. A preliminary isochore map (BEG, 1980) shows thickening of the unit to the east of the dome. The lower Carrizo reflects a period of alluvial deposition followed by transgressive, delataic-lagoonal deposition over the domal area during the latter part of the Carrizo deposition.

The Reklaw Formation overlies the Carrizo and it is probably the most distinctive unit at the site. The basal portion of the Reklaw is an indurated, clayey, glauconitic, very fine sand interbedded with silts and thin, concretionary, ironstone layers. The upper portion of the Reklaw consists of glauconitic, micaceous clay. The thickness of the Reklaw at the dome varies from 20 to 37 meters (65 to 120 ft). Preliminary isochore maps (BEG, 1980) show thickening of the Reklaw to the east of the dome. The Reklaw Formation, also exposed northwest of the dome, was deposited under open to restricted marine conditions (Kreitler and others, 1980).

The Queen City, a fluvial sequence (Kreitler and others, 1980), is the most extensive formation exposed in the Palestine Dome area. The dominant lithology is an unconsolidated, fine sand with some clay and ferruginous material. The exposure is 38 meters (125 ft) thick (Hightower, 1958).

The Quaternary sediments partially consist of extensive Pleistocene terraces that cover much of the western and southwestern portions of the domal area. The terrace materials, which are composed of clays and sands with pebbles and gravels, are described as having been reworked from higher, older beds in higher depositional sites. However, Hightower (1958) notes that the terraces to the southwest may be in their original position as evidenced by a broad, gently rolling topography, contrasting with the topographic character in isolated patches of the terraces to the north. The terrace deposits to the northeast, averaging approximately 6 to 9 meters (20 to 30 ft) in thickness, are well-indurated, ferruginous cemented sand and ironstone, containing a few quartz pebbles.

In addition to the Pleistocene terrace deposits, the banks of the creeks in the area of Palestine Dome are lined with Recent alluvium. This material consists of sand and pebbles of chert, quartz, and some limestone, as well as metamorphic rock, derived and reworked from older beds at higher elevations.

7.3.2.1.3 Structure - Palestine Salt Dome is a piercement dome typical of those found in the East Texas Embayment. The steep, quaquaversal dips in flanking beds exhibit intensive fracturing and faulting and an overall structural relief of about 1,981 meters (6,500 ft) (Hightower, 1958) (Figure 7-26). The circular shape of the salt stock is reflected in the topography and outcrop patterns. Tertiary sediments have been arched symmetrically around the dome, forming concentric, circular outcrop patterns with older strata exposed inward to form a structural inlier (Figure 7-26). Radial dips, generally steep, suggest that the Tertiary strata have been warped upward by the salt movement rather than having been pierced. Structural dips in Tertiary exposures around the near periphery of the dome range from 45 to 55 degrees, gradually decreasing away from the dome. At about 4 km (2.5 mi) from the dome center, dips are 1 to 2 degrees toward the southeast, consistent with the regional dip.

Outcropping beds of Tertiary sediments around the periphery of the dome are thinner than is typical of the section in areas away from the dome. This condition is indicative of domal uplift contemporaneous with deposition. It is also possible that, in addition to depositional thinning, compaction and attenuation of incompetent sediments during diagenesis may have occurred during uplift and piercement by the salt.

Rocks of the Comanchean and the Gulfian Series outcrop on the north side of the dome and at Duggey's Lake. The surface of the salt mass may dip less steeply on the north side of the dome, causing isolated blocks of these Cretaceous beds to be uplifted rather than pierced. The dips in these blocks vary from 45 to 70 degrees. Small patches of Navarro, Taylor, and Midway are exposed around Duggey's Lake.

Some of the sediments overlying the dome mapped as Quaternary terrace deposits may, in fact, belong to the Wilcox Group. The two units are difficult to distinguish in the outcrop because both weather to loose, sandy soils.

A major fault system at the surface (Figure 7-26) exhibits a radial pattern of normal faults with greatest displacement near the center of uplift, and decreasing outward for about 3 km (2 mi). The maximum amount of throw mapped is approximately 427 meters (1,400 ft) on the base of the Austin Group. Other radial faults have throws ranging from 30 to 107 meters (100 to 350 ft) measured on the base of the Reklaw. Some lineaments mapped by BEG correspond in orientation and location to these faults; however, other known faults in the domal area have not been obviously related to lineaments (Figure 7-29).

A fault of limited extent which strikes tangentially to the periphery of the salt mass has been mapped (Figure 7-26). Brecciated and fractured zones typically found along the tangential faults are also associated with most of the supradomal

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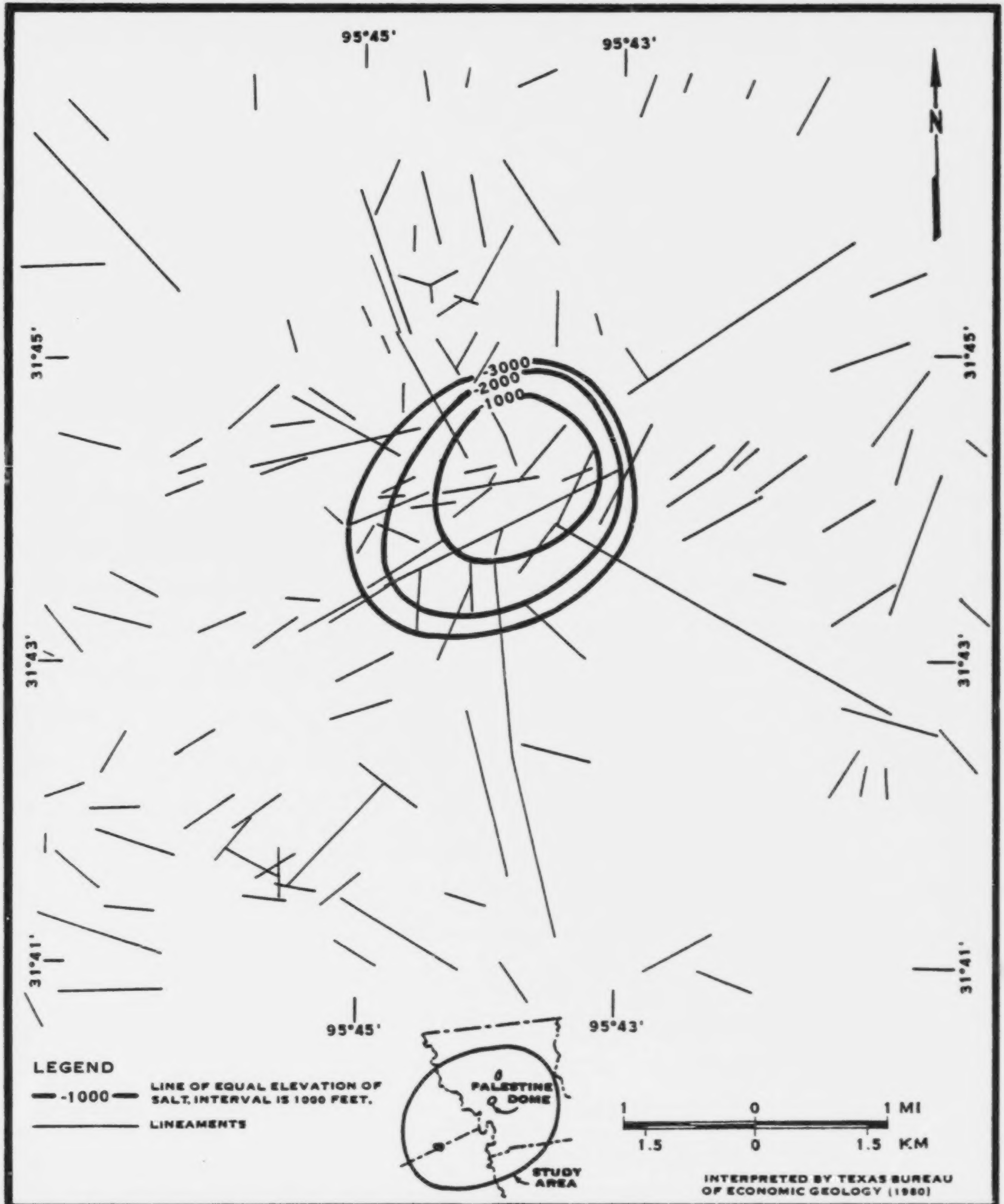
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LINE OF EQUAL ELEVATION OF SALT, INTERVAL IS 1000 FEET.
LINEAMENTS
PALESTINE DOME
STUDY AREA
1 0 1 MI
1.5 0 1.5 KM

INTERPRETED BY TEXAS BUREAU
OF ECONOMIC GEOLOGY (1980)

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NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
PALESTINE DOME AREA
LINEAMENT MAP

JOB NO. MV9600 FIGURE 7-29

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187

faults. Dips on the major fault planes range from 45 to 70 degrees. Smaller faults, some with displacements of less than 1.5 meters (5 ft), have higher dip angles varying from 70 to 90 degrees. The fault pattern at Palestine Dome is distinctive in the alternation of upthrown and downthrown wedge blocks that narrow toward the center of uplift (Figure 7-26).

7.3.2.2 Subsurface Geology: The stratigraphy of the subsurface at Palestine Dome includes the Late Triassic Series, Early and Late Jurassic Series, and the Comanchean and Gulfian Series of the Cretaceous System. The salt doming has caused the beds nearby to develop steep dips. Well data and preliminary isochore mapping by BEG in the vicinity of the dome were used to augment interpretation of the lithology and measurement of the stratigraphic section on the domal flanks not described from surface exposures over the dome. Wells near the dome have penetrated no beds older than the Travis Peak Formation of the Trinity Group; accordingly, local lithological variations in older units are not known, and seismic data are not available for estimates of thickness. However, the lithology and thicknesses of these units are not believed to differ significantly from those described in the subsurface geology of the East Texas Study Area (Section 6.2.2 and Table 6-1). Only the units that are not exposed at Palestine will be discussed in this section.

7.3.2.2.1 Lower Cretaceous - The Trinity Group of the Comanchean Series in the subsurface at Palestine Dome consists of the Travis

Peak Formation, the Pettet Limestone, the Glen Rose Subgroup (Lower Glen Rose, Ferry Lake, and the Upper Glen Rose Formations), and the Paluxy Formation. The descriptions and thicknesses of the Trinity Group are necessarily inferred from the electric log of Well 20-15, located adjacent to the east side of the dome. The upper 61 meters (200 ft) of the Travis Peak Formation are composed of interbedded silty shales and sandstones. Overlying the Travis Peak is the Pettet Limestone, consisting of 149 meters (490 ft) of interbedded shale and limestones. Above the Pettet Formation is the Lower Glen Rose Formation of the Glen Rose Subgroup, consisting of 290 meters (950 ft) of interbedded shales, limestones, and sandstones. The Lower Glen Rose Formation grades upward into the Ferry Lake Formation, which consists of 165 meters (540 ft) of anhydrite interbedded with shale and dense limestone and which is conformably overlain by the Upper Glen Rose Formation, consisting of 229 meters (750 ft) of microcrystalline limestone interbedded with fissile shale with some anhydrite stringers near the base. The Upper Glen Rose is overlain by the Paluxy Formation, consisting of sandstone and shale with some limestone, transitional to the overlying Fredericksburg Group.

The Fredericksburg Group is composed of the Goodland and Kiamichi Formations. In Well 28-25, 6.4 km (4 mi) southeast of the dome, the Goodland Limestone has a thickness of approximately 122 meters (400 ft), while the overlying shales of the Kiamichi have a total thickness of 14 meters (45 ft).

The units of the Washita Group below the Buda (from the bottom up) consist of the Duck Creek Limestone, Duck Creek Shale, and the Fort Worth, Denton, Weno-Paw Paw, Main Street, and Grayson Formations. From the base of the Duck Creek Limestone to the top of the Main Street Limestone the units consist of alternating beds of dense limestone and fissile shale with a thickness of 253 meters (830 ft) in Well 28-25. The uppermost formation, the Grayson, is 15 meters (50 ft) thick in this well and it consists of fissile shale interbedded with thin beds of dense limestone.

7.3.2.2.2 Structure - The structural development of Palestine Dome appears to have been similar to that at Keechi Dome, 10 km (6 mi) to the north. Structural similarities include upwarping of the sediments in the immediate vicinity of the dome, thinning of the Cretaceous and lower Tertiary section toward the dome, and intensive faulting. It is concluded that the Palestine Dome, like Keechi Dome, has reached the truncation stage of dome development (Kreitler and others, 1980).

Structural uplift of the strata adjacent to the flanks of Palestine Dome exposed Cretaceous to lower Tertiary beds over the dome flanks. Similar to the pattern at Keechi Dome, the oldest, Lower Cretaceous Buda Formation outcrop pattern is asymetric over the north flank of the dome (Figure 7-26), on which 1,981 meters (6,500 ft) of structural relief has been measured from supradomal wells. The Buda, the oldest exposed unit, is surrounded by younger units from the base of the Upper Cretaceous to the lower

Tertiary. The actual surface center of the dome, depressed either by solution collapse or by graben development in the subsurface, is occupied by Duggey's Lake. The lake is bordered on the east, south, and west by Quaternary terrace deposits. Therefore, it is not known if the Lower Cretaceous beds have been uplifted at other locations around the dome, though obscured by the terrace material. The dome apparently has pierced the entire Cretaceous section; however, there is no evidence of piercement of the Tertiary section. The Cretaceous and lower Tertiary beds dip away from the domal center and, according to Hightower (1958), the steepest dip ranges from 45 to 70 degrees in the oldest Cretaceous units and is about 50 degrees in the bordering Tertiary beds.

Uplift of the beds adjacent to Palestine Dome is associated with thinning of the entire section toward the dome. This is demonstrated through preliminary mapping and it is substantiated in an east-west cross section adapted from BEG (Figure 7-28). Studies by Hightower (1958) showed the combined Woodbine-Eagle Ford section to be 305 meters (1,000 ft) thick in Well 20-5, compared to 38 meters (125 ft) thick near the center of the dome. Hightower postulates that the thinning of the section at the dome is related to the combined circumstances of deposition contemporaneous with dome growth (stratigraphic thinning) and of movement subsequent to deposition (structural thinning or attenuation), affecting incompetent beds.

Preliminary structural maps of the Upper Cretaceous and lower Tertiary sections by BEG (1980) do not indicate the presence of any closed rim synclines around Palestine Dome. The lack of rim synclinal development is similar to the situation described at Keechi Dome. The synclines mapped suggest instead a reversal of regional dip onto the structural highs at Palestine Dome, Keechi Dome to the north, and over the domal structure of Long Lake Oil Field to the south. Complex structural development occurring over the salt ridge, which presumably spawned Palestine, Keechi, Concord, and possibly Butler Dome, has obscured any clear evidence of rim syncline development related to salt withdrawal.

Faulting at Palestine Dome has been extensive, as demonstrated by surface mapping (Figure 7-26). The radial pattern of tensional faulting is a series of alternating up-and-down, pie-shaped blocks with boundaries converging toward the domal center. Unlike Keechi Dome, the up-and-down blocks and radial pattern at Palestine do not appear to branch from the major faults which cut across the dome top. However, with much of the center of Palestine Dome obscured by Duggey's Lake and surrounding terrace deposits, the possibility of a fault pattern similar to Keechi's cannot be dismissed. Displacement on the major faults is greatest near the center of the dome, decreasing outward. Hightower (1958) mapped 427 meters (1,400 ft) of displacement on the base of the Austin Chalk on a major fault north of the dome. He also estimated throw on the major faults to be between 30 and 107 meters (100 to 350 ft) when measured on the base of the Reklaw Formation. The dip on the major fault planes was estimated to be approximately 45 degrees. Only one fault has been found not to duplicate the radial strike south of the dome; it is arcuate, paralleling the periphery of the dome. Although no central graben has been mapped, Hightower has suggested (personal communication, 1977) that a graben could account for the depression occupied by the saline lake over the top of the dome. The depression has also been attributed to collapse as a result of dissolution following salt mining activities at the dome from the early 1900's to the late 1920's.

In addition to faulting over Palestine Dome, preliminary mapping by BEG of the Upper Cretaceous and Tertiary horizons indicates faulting south of the dome which is associated with the domal structure at Long Lake Oil Field, or possibly with the Mt. Enterprise Fault Zone. Small east-west-trending grabens, with minor throws of from 15 to 30 meters (50 to 100 ft), are mapped only in the Woodbine-Midway interval.

Hightower (1958) suggests that initial dome growth occurred during the Late Jurassic. Salt dome growth occurred contemporaneously with deposition and continued during the Cretaceous and Tertiary, as indicated by thinning of the beds domeward. The structural relief, stratigraphic thinning, and normal faulting at the dome, along with the absence of secondary rim synclines or collapse features and lack of overhang development, suggest that Palestine Dome approaches the truncation stage (Kreitler and others, 1980).

7.3.3 MINERAL RESOURCES: Currently, there is no significant mineral resource extraction taking place at Palestine Dome. However, from the early 1900's to the late 1920's both salt and lignite were mined. Limited petroleum exploration activities at Palestine have failed to develop either oil or gas production. However, at Long Lake Oil Field, 5 km (3 mi) to the south of the dome, significant production of hydrocarbons has developed since discovery in 1933. Mineral resources at Palestine Dome are shown in Figure 7-30.

Palestine Salt and Coal Company operated at the dome from the early 1900's to the late 1920's, extracting an estimated 764,600 m^3 (1,000,000 yd^3) of salt from brine wells. The removal of this volume of material from beneath the surface of the ground may account for at least 0.6 meter (2 ft) of subsidence over the dome and the development of Duggeys Lake, previously known as Salt Works Lake (Powers, 1926). The total number of brine wells drilled at the dome is not known; however, many small, circular sinks have been tentatively identified as well sites by interpretation of aerial photos and field investigation. Future development of the salt resources at Palestine Dome is not likely because the region appears to be adequately supplied by the Morton Salt Company's operations at nearby Grand Saline Dome in Van Zandt County.

The Upper Wilcox Group contains major lignite deposits (Kaiser, 1974) and it is found in the outcrop in a concentric pattern around Palestine Dome. Kaiser reports two to three seams with a total thickness of 2.2 meters (7.5 ft). The lignite deposits at the dome were worked by Palestine Salt and Coal Company to fuel the brining plant operations described above. Mine shafts found at the dome site were abandoned when the lignite operation was

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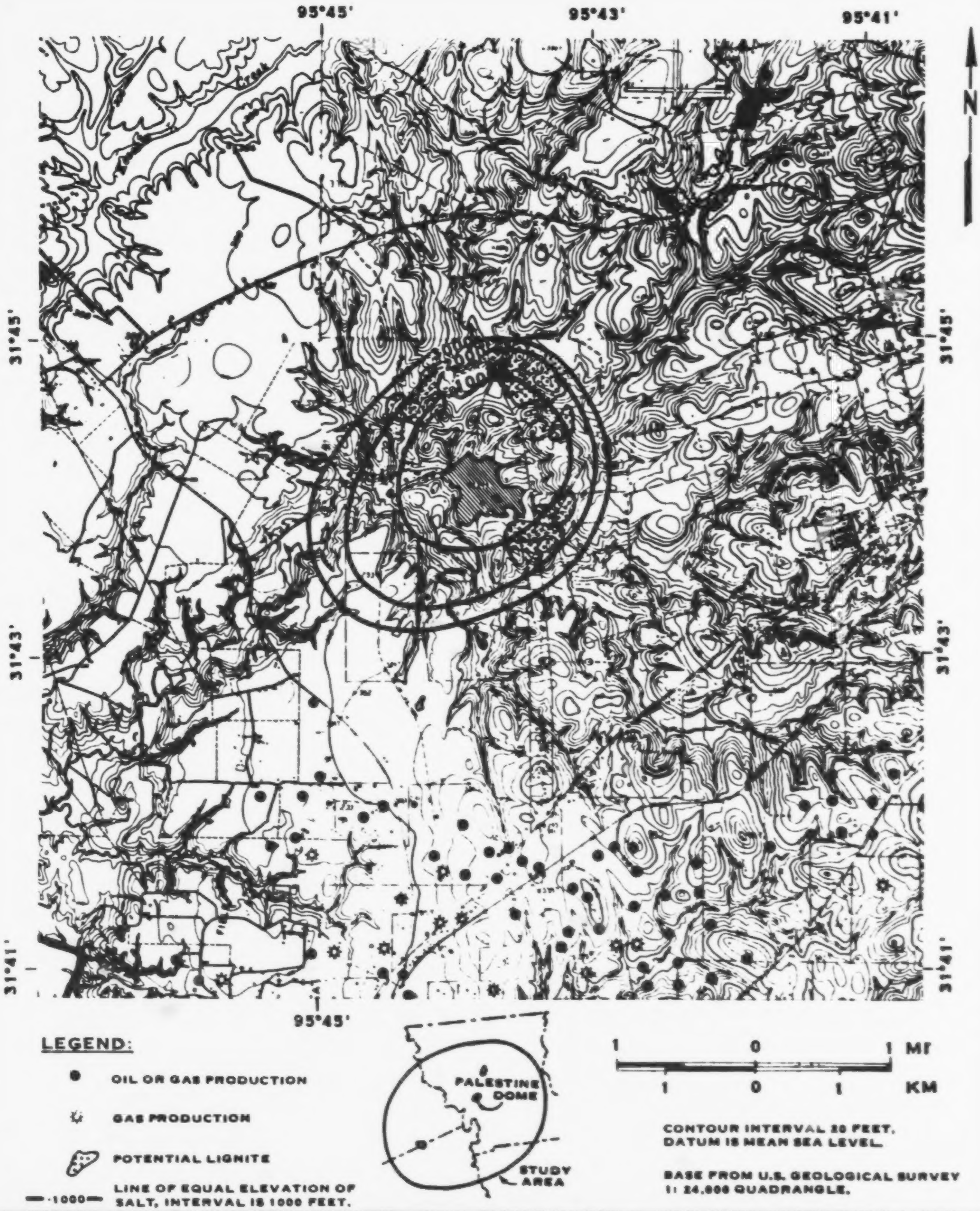
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CONTOUR INTERVAL 20 FEET.
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NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
PALESTINE DOME AREA
MINERAL RESOURCE DEVELOPMENT

JOB NO. MV9600 FIGURE 7-30

195

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discontinued concommittently with cessation of salt operations in the late 1920's. Future lignite extraction is feasible in the domal area.

Palestine Dome has been labeled "petroleum barren" by Netherland, Sewell & Associates (1975). Exploration activities at the dome have been limited to five wells drilled during the period 1930 to 1962. Exploration objectives at the dome involved the sands of the Woodbine Group and one test to the Travis Peak Formation. Oil and gas have been produced from various reservoirs at the Long Lake Field, including those at Pecan Gap, Sub-Clarksville, Woodbine, Rodessa, and Pettet. Status reports of the various Long Lake fields over the past 5 years of record (Texas Railroad Commission, 1974-1979) indicate oil production to be constant and gas production to be declining. Future petroleum development at Palestine Dome will depend upon the success of exploration drilling in testing the Lower Cretaceous and Upper Jurassic beds.

7.4 SUMMARY OF SELECTED DOMES

The geologic characterization of selected domes within the study area included Keechi, Oakwood, and Palestine Domes. The studies focused on the area within an 8-km (5-mi) radius of the domes.

Prior to the completion of the Area Characterization studies, ONWI directed that Palestine Dome be eliminated from further study because of unfavorable conditions (modern sinkhole development) reported by BEG. Therefore, the data base for Palestine

[redacted]

Dome was chiefly limited to existing geological information. Drilling at Oakwood Dome was curtailed before the field exploration was completed because it was feared that existence of numerous exploration wells through the overhang of the dome could threaten the containment integrity of the dome. Field exploration planned at Keechi was delayed in starting because of the questionable size of the dome.

The geometry of the salt domes was obtained from gravity modeling and wells penetrating the domes. True-scale cross sections along the major axis of the domes were furnished; the variation in thickness of the caprock and its correlation with the underlying salt were analyzed. The composition of the salt and caprock was studied by using the deep core hole drilled at Oakwood Dome.

Available surface and subsurface geologic data were evaluated to determine the growth history of the domes and the present condition of their stability. These studies have determined that at the time the domes were stabilized, Keechi and Palestine were both in a truncation stage, whereas Oakwood was in a mature growth stage. The growth stage is not a criterion in dome selection because the sediment-loading mechanism that apparently controls dome growth no longer exists; moreover, substantial deposition is not expected in the next 250,000 years. Except for evidence of possible minor movement near Oakwood, limited studies of Pleistocene terraces and Recent alluvium do not indicate rejuvenated dome growth at any of the domes.

The recognition of modern sinkhole development over Palestine Dome indicates the probability of structural collapse at depth, possibly because of dissolution of the caprock or salt initiated by solution mining operations.

The subject of mineral resources was evaluated by analysis of available and purchased data and special reports. This evaluation compared the domes according to known or potentially economic deposits that would become unproduceable because of construction of a repository. All three Texas domes are considered to have no significance for future mineral production. The following summarizes the study:

(1) The potential for future hydrocarbon production at Oakwood Dome is considered to be greater than at Palestine or Keechi because productivity has been demonstrated; however, current production at Oakwood is declining.

(2) Limited lignite production may be possible at Keechi and Palestine Domes if economic and technical conditions change.

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8 HYDROLOGIC CHARACTERIZATION OF THE EAST TEXAS STUDY AREA

The purpose of this chapter is to discuss the surface and subsurface hydrology of the study area and of selected domal areas. It is intended for use as an information base to aid in the selection of specific domes for further study.

The scope of this chapter includes characterization of the hydrology of the study area, with emphasis on the hydrology around Oakwood and Keechi Salt Domes. Regional and near-dome surface-water hydrology is described, and preliminary analyses of flooding potential from streams over domal areas are presented. Regional and near-dome ground-water hydrology are also described and preliminary analyses are presented which relate estimated average ground-water flow times along vertical flow paths in the subsurface to the base of fresh water at candidate domes.

The East Texas Study Area (Figure 8-1) is located primarily within the Trinity River watershed. A small portion of the study area extends into the Neches River watershed. The study area is about 3,367 km^2 (1,300 mi^2), including parts of Anderson, Freestone, Leon, and Houston Counties in northeastern Texas.

The hydrology of the East Texas Study Area has been described in county, statewide, and regional reports. Tarver (1966) presented information on the ground-water resources of Houston County, Texas. Guyton and others (1972) presented the same type of information for Anderson, Cherokee, Freestone, and Henderson Counties in Texas. Peckham (1965) investigated the ground-water resources of Leon County, Texas. The Texas Bureau of Economic

Geology (BEG) is currently studying the hydrogeology of the East Texas Salt Basin, including the study area in the vicinity of the candidate domes (Kreitler, 1978). A report by the U.S. Geological Survey (USGS) entitled Geohydrology of the Northeast Texas Salt Dome Basin and Selected Domes is in draft and under review at USGS headquarters in Reston, Virginia.

8.1 HYDROLOGIC FIELD DATA-COLLECTION PROGRAM, EAST TEXAS STUDY AREA

A field program was designed, in consultation with BEG, to collect hydrologic data within the study area. The program included hydrogeologic data-collection sites in the vicinity of Palestine, Oakwood, and Keechi Domes. However, Palestine Dome was withdrawn from consideration as a potential repository site before the field data-collection program began because of the evidence of modern dissolution and collapse above shallow caprock and salt resulting from a brining operation that was discontinued in 1937.

Field data-collection efforts were curtailed in the fall of 1979 by direction of the Office of Nuclear Waste Isolation (ONWI) (Law Engineering Testing Company, 1979). Work at Oakwood Dome was curtailed because ONWI believes that the existence of numerous exploration wells through the overhang of the dome will threaten the containment integrity of the dome. The work planned at Keechi Dome was postponed because of the dome's questionable size for use as a storage facility. New gravity data indicate that the size of Keechi Dome may be adequate; however, a high-resolution seismic survey did not confirm the size and shape of the dome.

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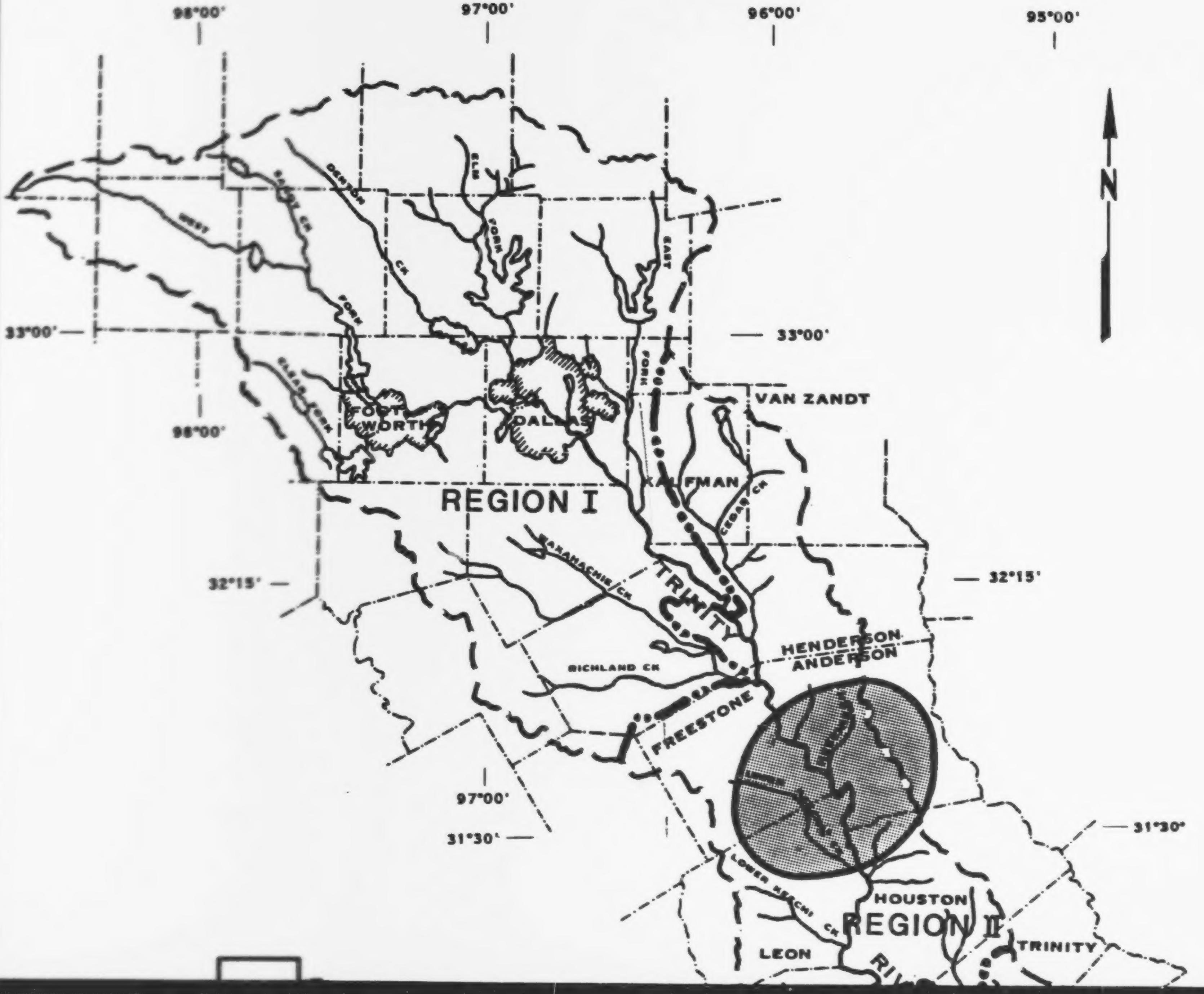
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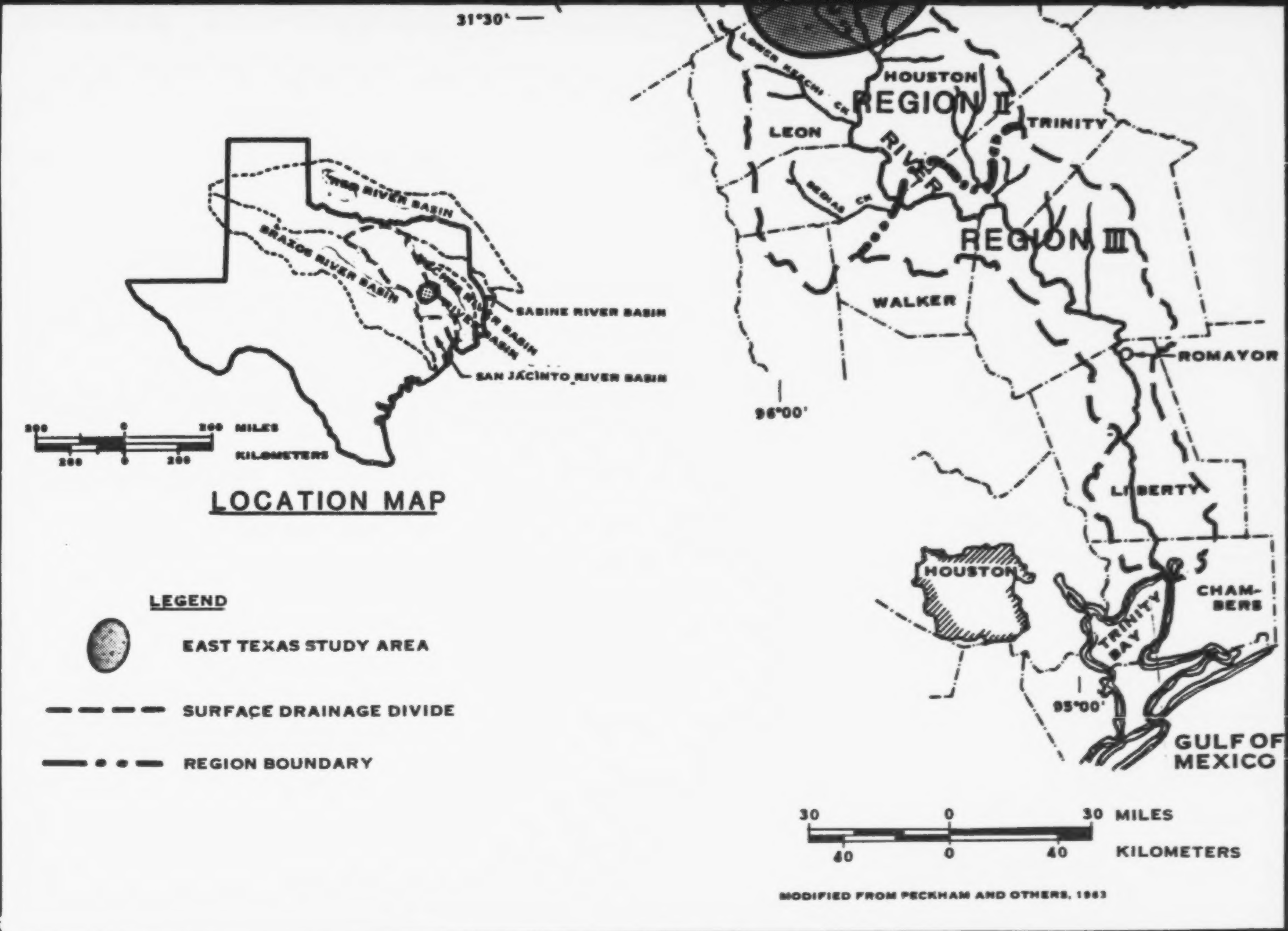
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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

LOCATION AND EXTENT OF STUDY AREA RELATIVE TO TRINITY RIVER WATERSHED

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FIGURE 8-1

The field data-collection program at Keechi Dome had not begun when the curtailment was ordered, but the program at Oakwood Dome was ongoing. Drilling operations were in progress at two hydrogeologic data collection sites. Drilling operations had been completed at the geologic data collection site and the shallow boring sites. The locations of sites where hydrogeologic data were collected prior to curtailment of operations are shown in Figures 7-1 and 8-2.

8.1.1 SURFACE WATER: Surface-water flow data were collected in the field during this investigation by USGS and BEG. Additional information needed for regional and dome-specific studies was obtained from published reports or was computed using standard techniques.

A description of geomorphology and drainage of the study area is presented in Chapter 6 of this report.

8.1.2 GROUND WATER: Hydrogeologic data-collection techniques used at each site included geophysical logging, aquifer testing, water level measuring and water sampling for chemical analysis. Geophysical logs were utilized to define the vertical location, thickness, and lithology of hydrogeologic units. Aquifer tests were used to obtain data for computing the hydraulic properties of hydrogeologic units. Water levels aided in defining directions and rates of ground-water movement and water samples were used to relate the chemical composition of water to directions and rates of flow.

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Sidewall cores were taken in some wells. Continuous core samples were taken in Wells TOH-2AO and TOG-1. These samples were obtained for laboratory analysis of permeability, porosity, grain density, and grain-size distribution.

Methodologies used to collect and analyze hydrogeologic data are summarized in the appendix.

8.1.3 WATER CHEMISTRY: A water chemistry data-collection program was designed to define the relationship of surface water to ground water, regional ground-water chemistry of the various aquifers, and directions of ground-water movement. Conductance, pH, dissolved oxygen, and temperature were measured by USGS at selected stream locations in the vicinity of candidate domes. Water samples were collected at some of these stream locations and analyzed for common elements and specific trace elements. Water samples were also collected from each well at the hydrogeologic and geologic data-collection sites. These samples were analyzed similarly. Selected physical properties of the water samples also were measured.

8.2 HYDROLOGIC CHARACTERIZATION OF THE EAST TEXAS STUDY AREA

Regional hydrology in the study area was characterized by integrating data from the literature with the limited data collected in the field. An understanding of the regional hydrology is an important aid in defining the hydrology in the vicinity of specific domes.

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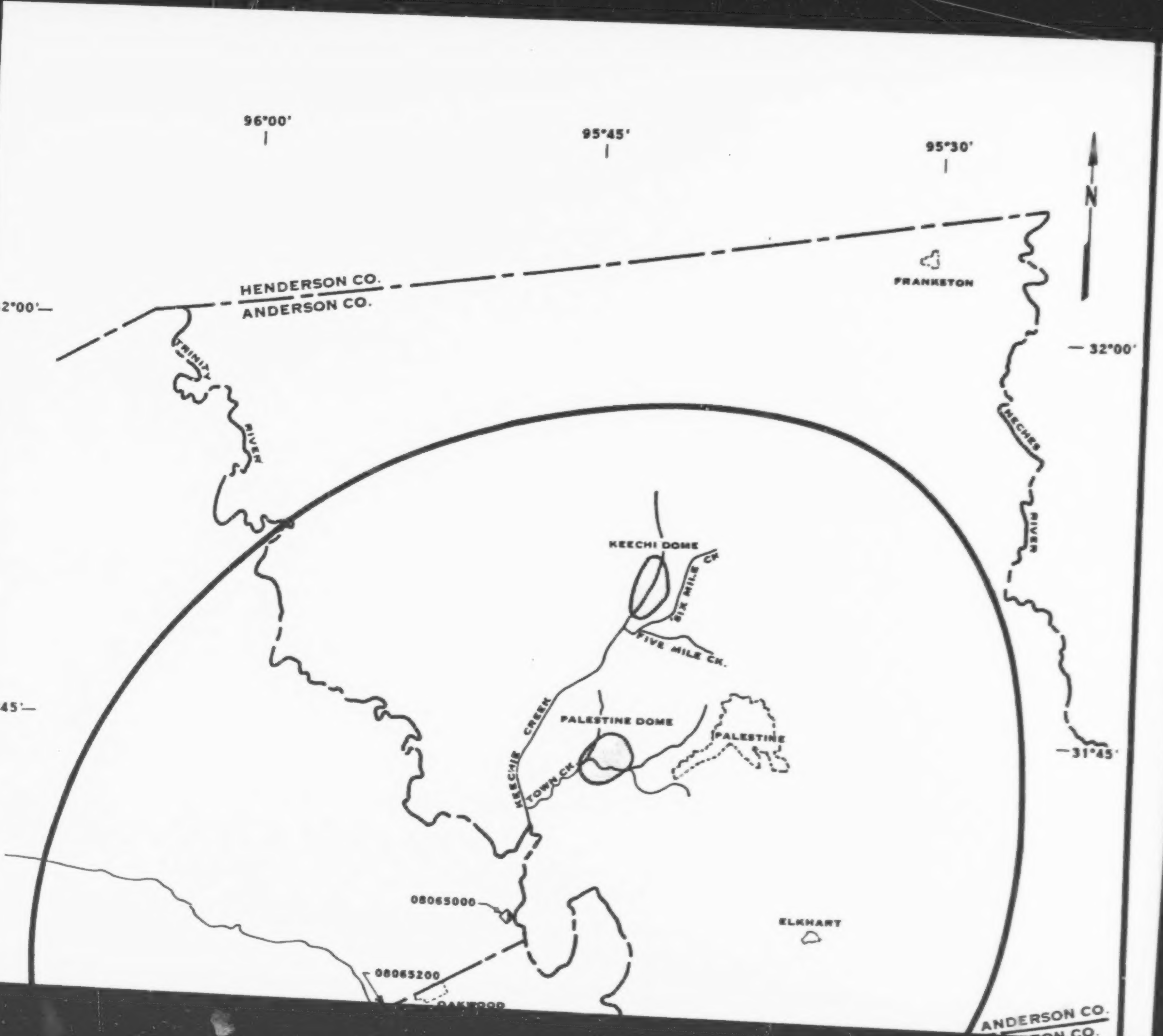
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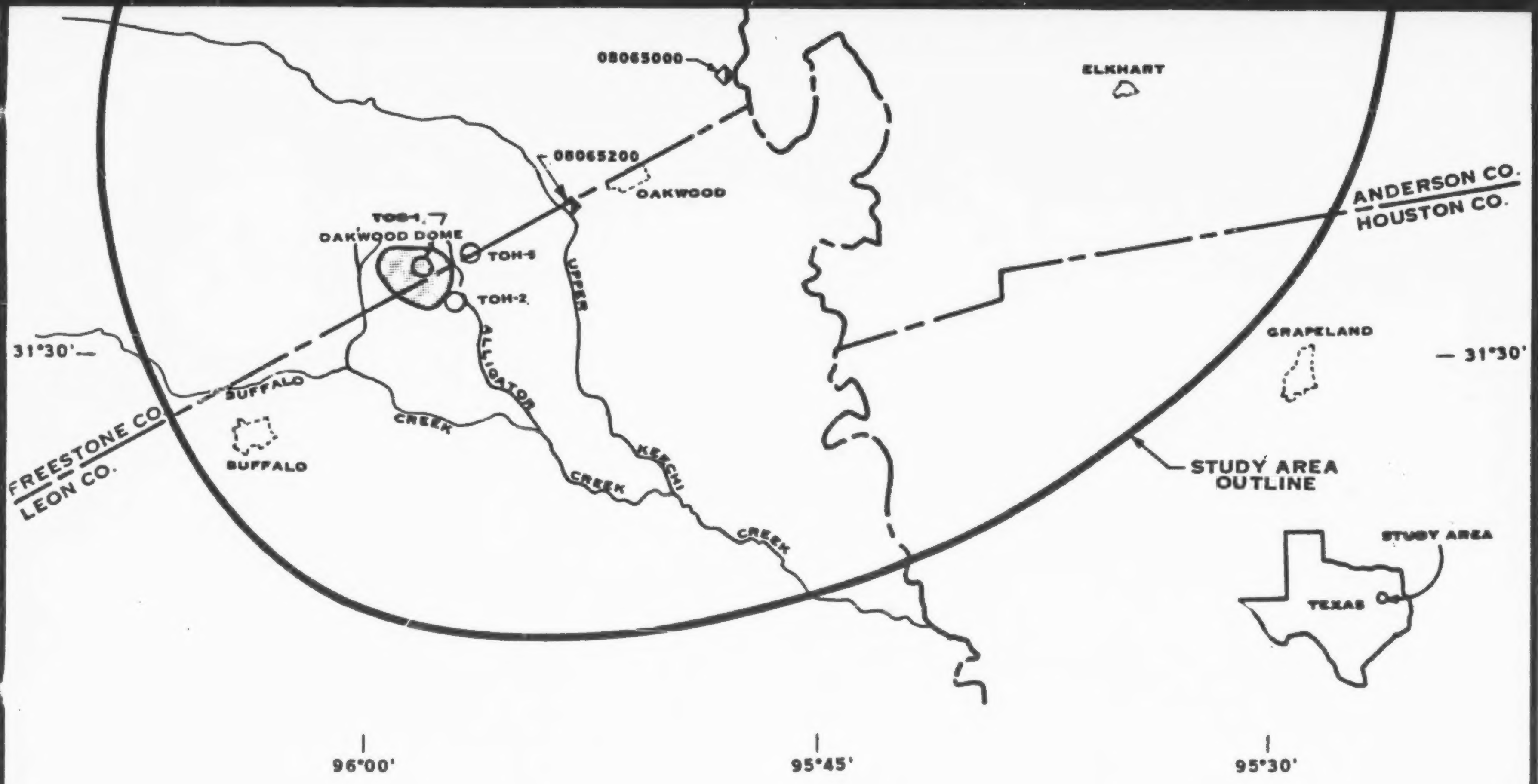
08065000
ELKHART
08065200
OAKWOOD
ANDERSON CO.
HOUSTON CO.
TOG-1
OAKWOOD DOME
TOH-5
TOH-2
UPPER
ALLIGATOR
31°30'
31°30'
GRAPELAND
BUFFALO
CREEK
BUFFALO
FREESTONE CO.
LEON CO.
CREEK
KEECHI
CREEK
STUDY AREA OUTLINE
STUDY AREA
TEXAS
96°00'
95°45'
95°30'

5 0 5 MILES
8 4 0 8 KILOMETERS

LEGEND

TOH-2 ○ SITE WHERE DATA WERE COLLECTED.

TOH IS DESIGNATION USED FOR HYDROGEOLOGIC DATA-COLLECTION SITE AT OAKWOOD DOME.
TOG IS DESIGNATION USED FOR GEOLOGIC DATA-COLLECTION SITE AT OAKWOOD DOME.

◆ USGS STEAM-GAUGING STATION.

● SALT DOME SHOWING LOCATION OF -2000 FT., MSL CONTOUR ON SALT SURFACE.

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REVISED	[illegible]	DATE	[illegible]
REVISED		DATE	
APPROVED	[illegible]	DATE	[illegible]

T-1027- 1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA . GEORGIA

EAST TEXAS STUDY AREA

REGIONAL DRAINAGE AND LOCATION OF HYDROLOGIC DATA COLLECTION SITES

JOB NO. MV9600

FIGURE 8-2

8.2.1 REGIONAL SURFACE-WATER HYDROLOGY: The East Texas Study Area is located mostly within the Trinity River watershed (Figure 8-1). The Trinity River has a drainage area of about 46,620 km^2 (18,000 mi^2). Its headwaters are formed by the confluence of West Fork and Elm Fork Rivers near Dallas, Texas. It flows southeasterly from this confluence to enter Trinity Bay at the Gulf of Mexico.

The climate of the Trinity River watershed ranges from subhumid to humid and it is characterized by hot summers and mild winters. Yearly precipitation ranges from approximately 635 mm (25 in) near the headwaters of the watershed to about 1,270 mm (50 in) near the coast. The mean annual temperature for the watershed is 19 C (66 F) (Peckham and others, 1963).

The Trinity River watershed lies mainly within the physiographic region known as the Upper Gulf Coastal Plain. However, because of the watershed's large areal extent and differences in topography and rainfall, it has been divided into three regions for report purposes. The locations of these regions are shown in Figure 8-1.

Region I covers the northern 58 percent of the Trinity River watershed. The topography of Region I is characterized by a series of north-trending, alternating linear belts of treeless prairies and rolling timbered hills. The prairies are smooth to slightly rolling, whereas the timbered hills are characterized by low, rounded, sandy hills and knobs, vegetated by post oak. The topography is more rugged and varied in the western part of the region, with resistant rocks forming prominent westward facing escarpments in some areas. Major streams include West Fork, Elm Fork, Clear Fork, and East Fork of the Trinity River and Richland Creek. Mean annual precipitation ranges between 635 mm (25 in) in the west and 1,016 mm (40 in) in the east. Maximum rainfall in this region generally occurs during the months of April, May, and June (Peckham and others, 1963).

Region II covers the central 29 percent of the watershed. The topography in the northern part of Region II, including Kaufman and Van Zandt Counties and part of Henderson County, is flat to gently rolling. The remainder of the region is characterized by gently rolling to hilly topography. Small areas of prairie land occur in the southwest corner of the region. Major tributaries include Cedar Creek and Upper and Lower Keechi Creeks. Mean annual precipitation ranges from 1,016 mm (40 in) in Freestone County to 1,143 mm (45 in) in Trinity County. The wettest months are April, May, and December, and the driest are July and August (Peckham and others, 1963).

The East Texas Study Area is located in Region II. Palestine and Keechi Domes are located in the Keechie Creek watershed, and Oakwood Dome is located in the Upper Keechi Creek watershed (see Figure 6-5). Keechie Creek is a minor tributary of the Trinity River.

Region III covers the lower 13 percent of the watershed. Most of the region is characterized by gently rolling to hilly topography and heavily forested land. Topography in Chambers County and the southern part of Liberty County is flatter. Mean annual precipitation ranges from 1,143 mm (45 in) in Walker

County to 1,270 mm (50 in) in Chambers County (Peckham and others, 1963).

About 15 percent of the precipitation in the Trinity River watershed appears in streams as runoff. Runoff from the watershed above Romayor, Texas, the lowermost site where daily discharge is measured, averages 152 mm (6 in) annually. Runoff from sub-watersheds varies from 51 mm (2 in) in the upper part of the watershed to 178 mm (7 in) in the central part (USGS, 1978).

8.2.2 REGIONAL GROUND-WATER HYDROLOGY: Regionally, strata of principal hydrologic concern are those of Late Cretaceous and Tertiary ages. Beds of Cretaceous age dip east-southeasterly at an increasing rate gulfward from 4 to 19 m/km (20 to 100 ft/mi) (Guyton and others, 1972). North of Leon and Houston Counties beds of Tertiary age dip eastward into the Northeast Texas Embayment (whose axis is coincident with the East Texas Salt Basin), while south of Leon County they dip southeasterly into the Lower Gulf Coastal Province. (Refer to Volume I, Section 2.1 for a description of these structural features.) The thickness of these deposits increases downdip from their outcrop area. Cretaceous sediments consist of interbedded sands, shales, and calcareous deposits of fluvio-deltaic or shallow-marine origin. Tertiary sediments consist primarily of interbedded sand, shale, and clay. Surficial deposits of Quaternary age overlie deposits of Tertiary age. These deposits occur in stream valleys as terrace remnants and they are generally water-bearing. A detailed lithologic description of the sediments in the study area is given in Chapter 6 of this report.

Water-bearing deposits of Cretaceous age are exposed at the surface north of the study area (Figure 8-3). Recharge to these aquifers is derived principally from rainfall in the outcrop areas. Additional recharge may occur as a result of leakage between aquifers in areas south of these outcrops.

Exposed in the study area are deposits of Tertiary age (Figure 8-3). Ground-water recharge to these aquifers in this area is directly from precipitation. Hydraulic connection between these deposits and streams is common. Recharge may also occur as leakage between aquifers.

Piercement salt domes locally affect the dip, strike, and thickness of the geologic strata they penetrate, as well as of the overlying beds. The structural complexities around and over a salt dome may also influence its hydrologic relationship with the surrounding and overlying strata.

8.2.2.1 Hydrogeology of the Study Area: Water is present in all of the geologic deposits investigated in this study. The Woodbine Group, however, is assumed to be the lower limit of the ground-water reservoir for purposes of this study because it occurs at depths substantially below those that are generally of interest for proposed storage facilities in salt domes. The Woodbine Group may be water-bearing and could transmit appreciable amounts of water, but it is separated from the fresh-water aquifers of the Tertiary System by several hundred feet of confining layers. The water table in the Quaternary deposits is the upper limit of this reservoir (Table 8-1).

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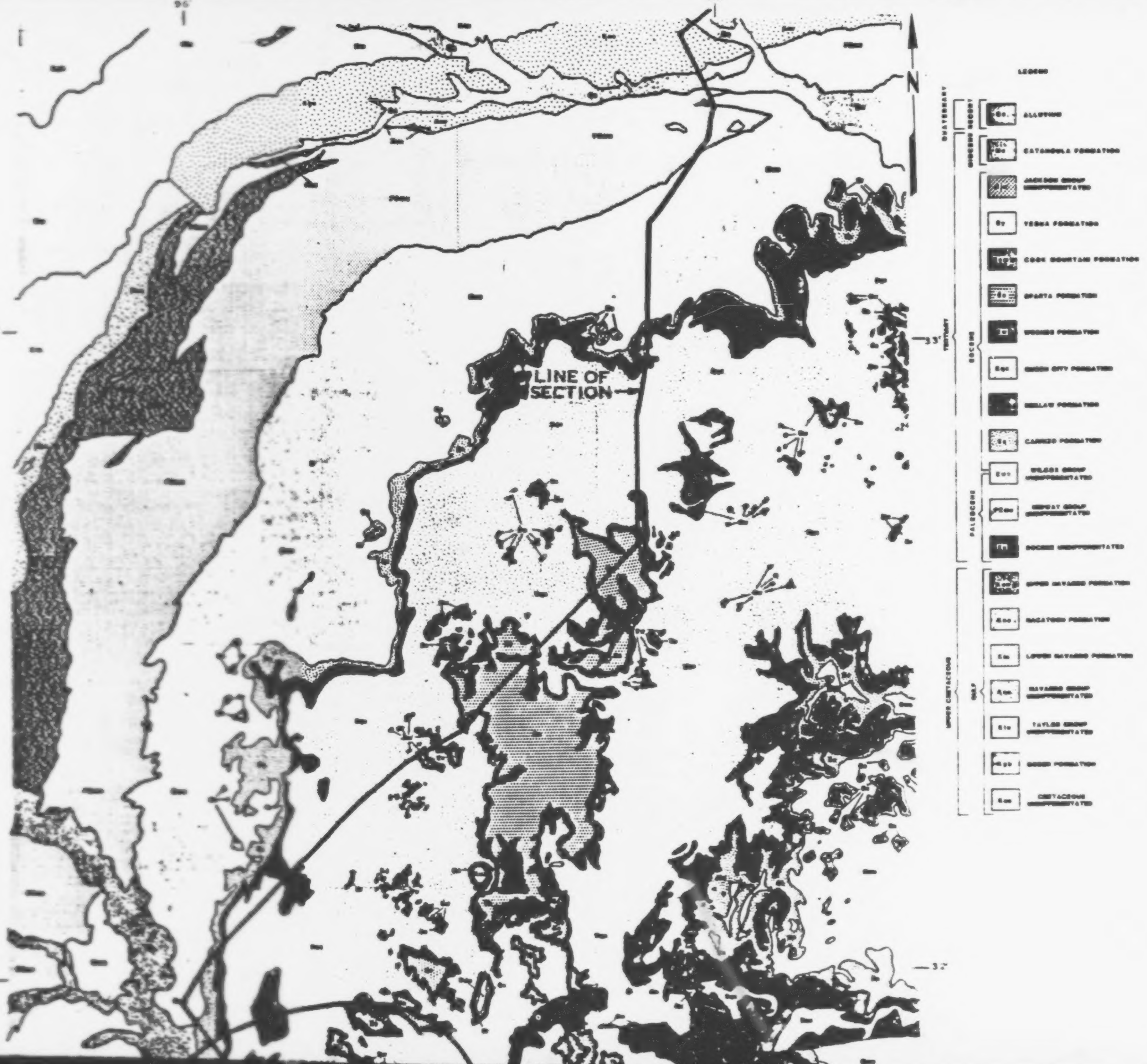
96°
95°
33°
32°
N
LINE OF SECTION
LEGEND
QUATERNARY
TERTIARY
EOCENE
PALEOCENE
UPPER CRETACEOUS
GULF
Qa ALLUVIUM
CATAHOULA FORMATION
JACKSON GROUP UNDIFFERENTIATED
Ey YEGUA FORMATION
COOK MOUNTAIN FORMATION
SPARTA FORMATION
WECHES FORMATION
Eqc QUEEN CITY FORMATION
RECKLAW FORMATION
Ec CARRIZO FORMATION
WILCOX GROUP UNDIFFERENTIATED
MIDWAY GROUP UNDIFFERENTIATED
UPPER NAVARRO FORMATION
NACATOCH FORMATION
LOWER NAVARRO FORMATION
NAVARRO GROUP UNDIFFERENTIATED
TAYLOR GROUP UNDIFFERENTIATED
CRETACEOUS UNDIFFERENTIATED

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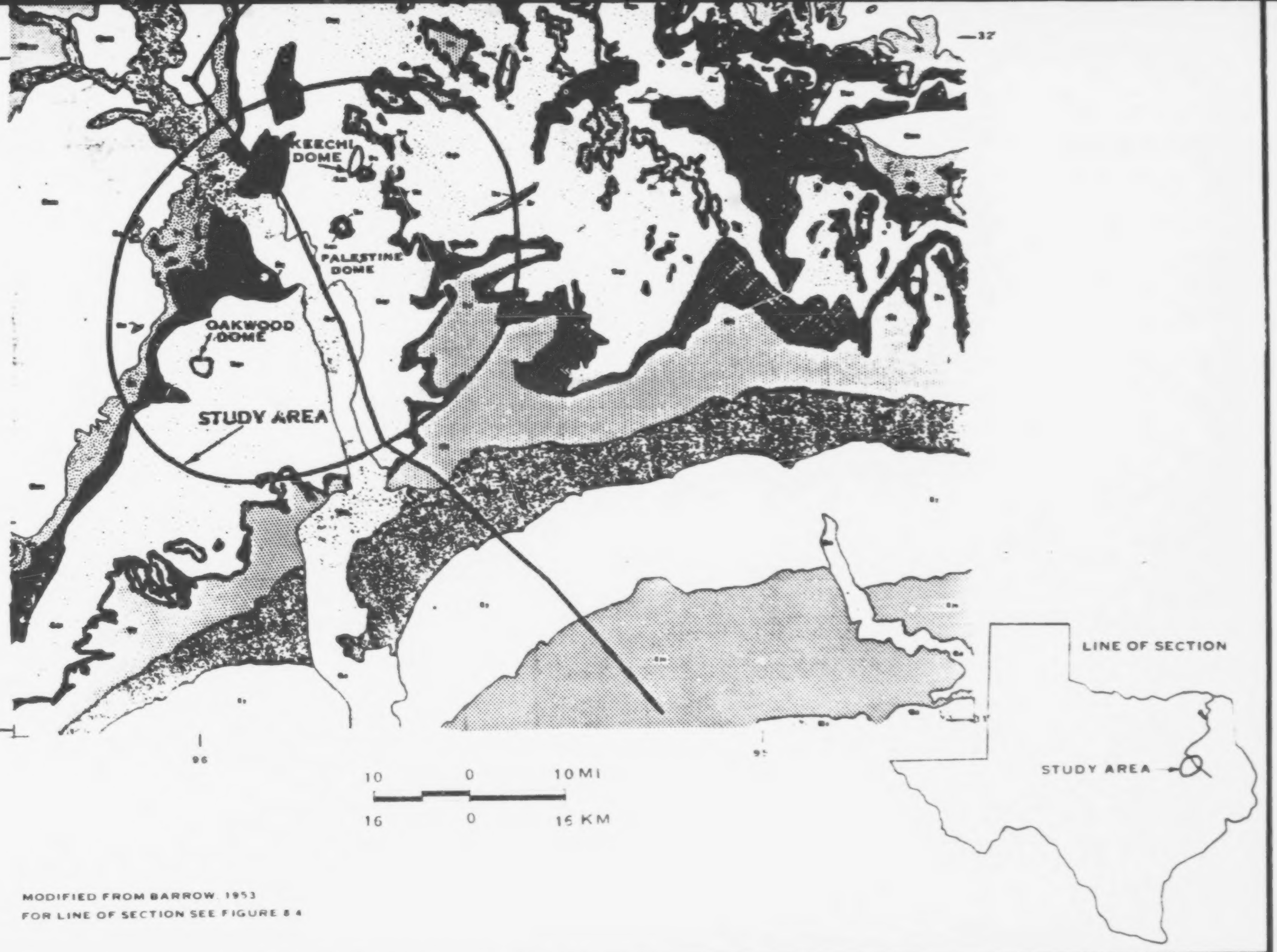

32°
32°
KEECHI DOME
PALESTINE DOME
OAKWOOD DOME
STUDY AREA
31°
31°
96
95
10 0 10 MI
16 0 16 KM
LINE OF SECTION
STUDY AREA

MODIFIED FROM BARROW, 1953

FOR LINE OF SECTION SEE FIGURE 8 4

PREPARED ______ DATE ______
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED Gmr DATE 5/06/81

T 1014-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

OUTCROP MAP FOR SELECTED HYDROLOGIC UNITS

JOB NO. MV960C

FIGURE 8-3

Regionally, the Nacatoch Formation of the Navarro Group and the Taylor and Eagle Ford Groups yield small amounts of poor-quality water in their outcrop areas north of the study area. The Woodbine Group, the most important aquifer system in the Upper Cretaceous, yields moderate to large quantities of water north and northeast of the study area where this group is close to the surface, though downdip from the outcrop. In the study area the depth to the Woodbine and the quality of the water have precluded its use as a source of water supply. Lithologic data for the Nacatoch Formation of the Navarro Group, Taylor, Eagle Ford, and Woodbine Groups, interpreted from geophysical logs of deep wells, indicate that their water-bearing and transmitting properties are significantly reduced in the study area.

Within the study area, beds of Tertiary age that are considered to be regional aquifers include (in ascending order) the Wilcox Group and the Carrizo, Queen City, and Sparta Formations of the Claiborne Group (Table 8-1). These deposits contain fresh water in their outcrop areas and for varying distances downdip. The Wilcox-Carrizo aquifer system constitutes the largest supply of fresh ground water in the study area (BEG, written communication, 1980).

The Wilcox Group and the Carrizo Formation of the Claiborne Group are generally considered one aquifer system, although each possesses distinct geologic and hydrologic characteristics. Lithologically, the Carrizo Formation consists of a well-sorted quartz sand with a few thin beds of shale. The sand is medium-grained near the base, grading upward to fine-grain sand. The

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TABLE 8-1
GENERALIZED STRATIGRAPHY & WATER BEARING CHARACTERISTICS OF GEOLOGIC UNITS IN THE EAST TEXAS STUDY AREA

SYSTEM	SERIES	GEOLOGIC UNIT		DOMINANT LITHOLOGY	WATER BEARING CHARACTERISTICS
Quaternary	Recent & Pleistocene		Terrace & Alluvium	Unconsolidated sand, silt, clay & some gravel	Aquifer not present everywhere in study area. Generally transmits small amounts of water to wells. Quality of water fair, but wells are easily contaminated by improper disposal practices.
TERTIARY	EOCENE	CLAIBORNE GROUP	Cook Mountain Formation	Glauconitic sand interbedded with silt and clay	Yields water in small amounts to domesic wells. Limited to 30-50 gpm in the study area. Water quality is variable with high total dissolved solids.
			Sparta Formation	Fine to medium-grained sand with glauconitic clay and silt	Transmissivity of this formation is moderate to high. It is a source of water supply to many communities in the study area. Water quality is good with low TDS. Some wells have high iron content.
			Weches Formation	Glauconitic sand and shale	Does not transmit water readily. It is not considered an acuifer.
			Queen City Formation	Medium to fine-grained sand interbedded with silt and clay	Transmissivity of this formation is low and yields of wells tapping this aquifer are generally less than 250 gpm. Water produced from this aquifer is of good chemical character, but can contain high nitrates in shallow wells.
			Reklaw Formation	Upper part is silty with carbonaceous clay, lower part is silty with some sand	Yields only small amounts of water in its outcrop. In the subsurface this formation does not readily transmit water to wells.
			Carrizo Formation	Upper portion is silty sand and clay. Lower portion is massive medium to fine sand	Yields large amounts of water to wells in the study area and is an abundant supply source. Water quality is good and water produced is soft and acceptable for a variety of uses.
	PALEOCENE		Wilcox Group	Interbedded fine-grained sand, silt and shale	Transmissivity is variable, generally less than that of the overlying Carrizo, but not as low as the Queen City. Lenticular nature of this group makes water supply development possible only locally. Water quality is similar to the overlying Carrizo Formation.
			Midway Group	Micaceous, calcareous shale with some thin beds of fine-grained sand.	Does not transmit water readily. It is not considered an aquifer.
UPPER CRETACEOUS	GULFIAN	NAVARRO GROUP	Upper Navarro	Silty shale interbedded with marl and siltstone	Does not transmit water readily. It is not considered an acuifer.
			Nacatoch Formation	Fine-grained sand, sandy clay, calcareous sandy marl	Yields small to moderate amounts of water in its outcrop only in the north central part of the study area. Water quality is variable.
			Lower Navarro	Limestone, marl, and clay	Does not transmit water readily. It is not considered an aquifer.
			Taylor Group	Clay, marl and chalk with some sandy marl	These units do not trasmit water readily in the study area. They are not considered to be aquifers.
			Austin Group	Chalk, marl and limestone	
			Eagle Ford Group	Shale with thin laminated beds of sandstone and limestone	
			Woodbine Group	Fine to medium-grained calcareous and non-calcareous sands and sandstones. Interbedded with shales	Information on this group's water-bearing characteristics in the study area is not available. Units in this group may be capable of transmitting small quantities of saline water to wells.

[redacted]

composition of the Wilcox Group ranges from lignite and shale to a quartz sand. It is composed of alternating beds of sand, sandy shale, shale, and lignite of variable thicknesses. The average transmissivity and hydraulic conductivity of the Carrizo Formation is 82,134 l/day (21,700 gal/day) per foot and 935 l/day (247 gal/day) per square foot, respectively (Myers, 1969), with a low transmissivity reported to be 48,448 l/day (12,800 gal/day) per foot and a high reported to be 117,335 l/day (31,000 gal/day) per foot (Peckham and others, 1963). Hydraulic characteristics of the Wilcox Group are more variable. Reported transmissivities range from a low of 5,299 l/day (1,400 gal/day) per foot to a high of 177,895 l/day (47,000 gal/day) per foot, and average 49,205 l/day (13,000 gal/day) per square foot. Hydraulic conductivity values average 341 l/day (90 gal/day) (Myers, 1969).

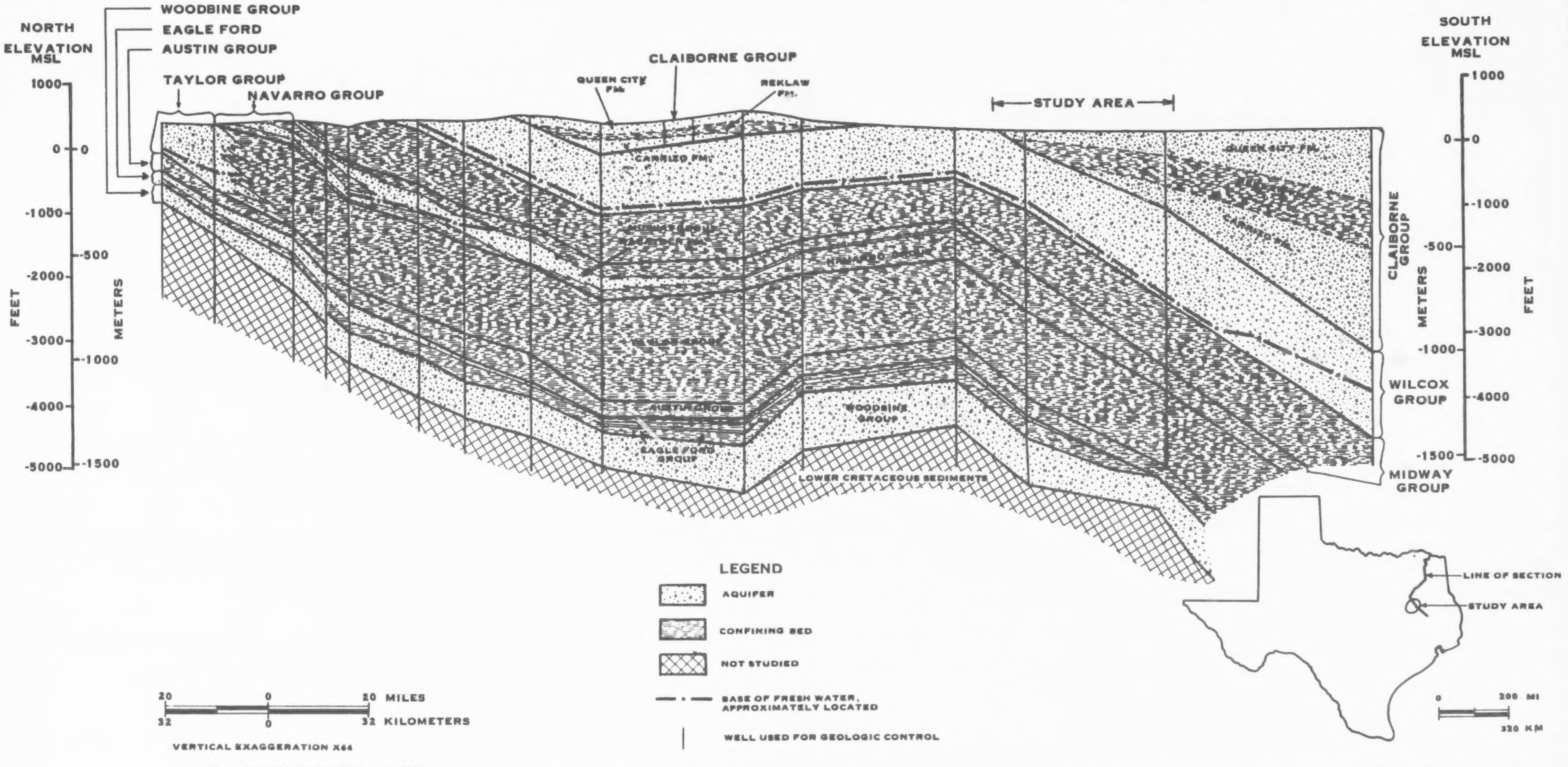
The Queen City Formation is not as important an aquifer in the study area as the Wilcox-Carrizo and Sparta aquifer systems. The Queen City Formation consists principally of cross-bedded, medium to very-fine-grain, micaceous sand. The sand beds are massive to thin and interbedded with shale and sandy shale. Reported transmissivities for this formation range from 9,462 to 11,355 l/day (2,500 to 3,000 gal/day) per foot, and reported hydraulic conductivities range from 121 to 269 l/day (32 to 71 gal/day) per square foot (Guyton and others, 1972). The heterogeneous character of the sediments of the Queen City Formation and the lenticular nature of the beds contribute to its lower hydraulic conductivities and transmissivities (Peckham and others, 1963).

The Sparta Formation consists of fine to medium-grain sand, grading upward to silty sand and clay with minor amounts of glauconite and lignite. The Sparta Formation thins from west to east within the study area. Transmissivity and hydraulic conductivity values of 70,969 l/day (18,750 gal/day) per foot and 1,060 l/day (280 gal/day) per square foot, respectively, reported by Peckham and others (1963) demonstrate good water-bearing characteristics for this aquifer. The Sparta is utilized extensively as a source of ground water in the study area where it is exposed or sufficiently thick.

Quaternary alluvial deposits along the Trinity River and its main tributaries furnish water for small industries and agriculture. Use of these deposits as a source of water supply is limited in the study area.

Confining beds which retard flow between aquifers in the study area are present in the Eagle Ford, Austin, Taylor, Navarro, and Midway Groups and in the Reklaw, Weches, and Cook Mountain Formations of the Claiborne Group. Figure 8-4 shows the relationship of water-bearing units relative to regional confining beds in the study area.

Aquifers of Tertiary age and younger all contain fresh water [less than 1,000 mg/l (1,000 ppm) total dissolved solids]. The base of the fresh-water zone (top of the saline-water zone) is at its highest elevation in the northwestern part of the study area. The elevation of the fresh-water base decreases to the east and south as the water-bearing formations thicken and the dip increases. Throughout most of the study area the fresh-water base approximately coincides with the base of the Wilcox Group.


NORTH
ELEVATION MSL
FEET
METERS
1000
0
-1000
-2000
-3000
-4000
-5000
0
-500
-1000
-1500
WOODBINE GROUP
EAGLE FORD
AUSTIN GROUP
TAYLOR GROUP
NAVARRO GROUP
CLAIBORNE GROUP
QUEEN CITY FM.
REKLAW FM.
CARRIZO FM.
MIDWAY GROUP
NAVARRO GROUP
TAYLOR GROUP
AUSTIN GROUP
EAGLE FORD GROUP
WOODBINE GROUP
LOWER CRETACEOUS SEDIMENTS
STUDY AREA
QUEEN CITY FM.
CARRIZO FM.
SOUTH
ELEVATION MSL
CLAIBORNE GROUP
WILCOX GROUP
MIDWAY GROUP
METERS
FEET
0
-500
-1000
-1500
1000
0
-1000
-2000
-3000
-4000
-5000
LEGEND
AQUIFER
CONFINING BED
NOT STUDIED
BASE OF FRESH WATER, APPROXIMATELY LOCATED
WELL USED FOR GEOLOGIC CONTROL
20 0 20 MILES
32 0 32 KILOMETERS
LINE OF SECTION
STUDY AREA
0 200 MI
320 KM

VERTICAL EXAGGERATION X64

GEOLOGY MODIFIED FROM CORE LAB., 1972

PREPARED		DATE	2/15/80
REVISED	JEP	DATE	11/17/81
REVISED		DATE	
APPROVED		DATE	2/12/80

T-1420-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
GENERALIZED HYDROGEOLOGIC CROSS-SECTION THROUGH THE EAST TEXAS STUDY AREA

JOB NO. MV9600

FIGURE 8-4

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In the southeastern part of the study area, however, more than 40 percent of the thickness of the Wilcox Group contains saline water (BEG, written communication, 1980). This condition may be the result of incomplete flushing of connate saline water by fresh water at these greater depths and thicknesses or the result of longer contact time of the fresh ground water with the surrounding environment. Figure 8-5 shows the elevation of the base of fresh water in the study area.

8.2.2.2 Water Levels and Water Movement: The potentiometric surface map (Figure 8-6) shows the elevation to which water rises in wells in the Wilcox-Carrizo aquifer system. Regionally, water levels range from a high of +122 to +152 meters (+400 to +500 ft) MSL in the outcrop area to the west and north of the study area to less than +61 meters (+200 ft) MSL south of the study area. The general shape of the potentiometric surface indicates that the Trinity River is a major discharge area of this aquifer system in the study area.

Observed water levels in the Queen City Formation are greater than those in the Wilcox-Carrizo aquifer, except near the Trinity River where the reverse situation occurs (BEG, written communication, 1980). This distribution of water levels suggests that downward leakage of water to the Wilcox-Carrizo aquifer occurs everywhere in the study area, except near the Trinity River where upward leakage occurs into the Queen City Formation.

Ground-water flow directions in the Sparta Formation are not well defined because the lack of data prevents the construction

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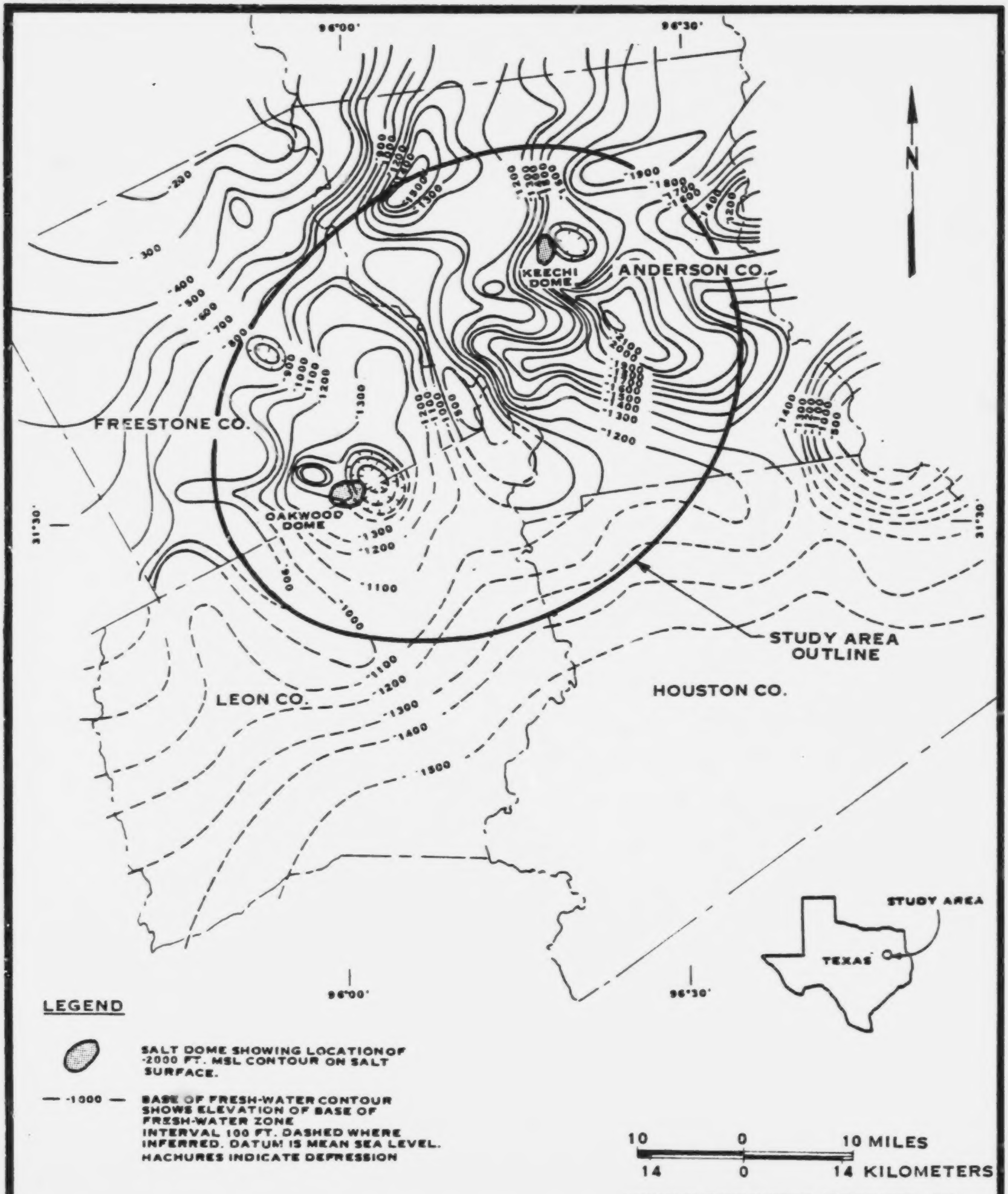
96°00'
96°30'
31°30'
N
FREESTONE CO.
ANDERSON CO.
LEON CO.
HOUSTON CO.
KEECHI DOME
OAKWOOD DOME
STUDY AREA OUTLINE
TEXAS
STUDY AREA
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
-2100
LEGEND
SALT DOME SHOWING LOCATION OF -2000 FT. MSL CONTOUR ON SALT SURFACE.
-1000 BASE OF FRESH-WATER CONTOUR SHOWS ELEVATION OF BASE OF FRESH-WATER ZONE INTERVAL 100 FT. DASHED WHERE INFERRED. DATUM IS MEAN SEA LEVEL.
HACHURES INDICATE DEPRESSION
10 0 10 MILES
14 0 14 KILOMETERS

MODIFIED FROM GUYTON AND OTHERS, 1972

PREPARED DATE
REVISED DATE
REVISED DATE
APPROVED DATE
T-1426-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
BASE OF FRESH - WATER MAP

JOE NO. MV9600 FIGURE 8-5

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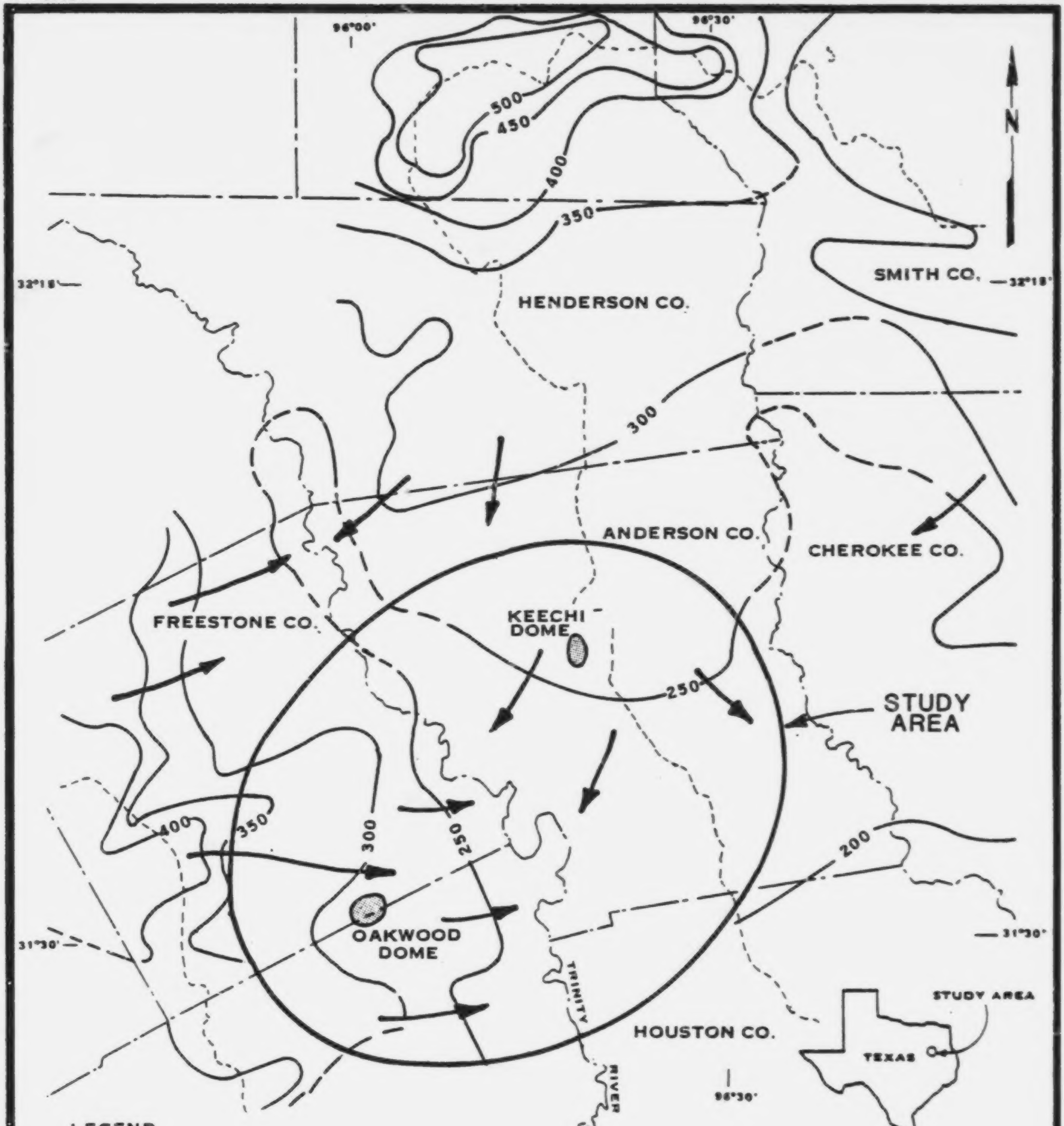
96°00'
96°30'
N
500
450
400
350
SMITH CO.
32°15'
32°15'
HENDERSON CO.
300
ANDERSON CO.
CHEROKEE CO.
KEECHI DOME
FREESTONE CO.
250
STUDY AREA
400
350
300
250
200
OAKWOOD DOME
31°30'
31°30'
TRINITY RIVER
HOUSTON CO.
STUDY AREA
TEXAS
95°30'

LEGEND

→ GENERALIZED DIRECTION OF GROUND-WATER FLOW

—300— POTENTIOMETRIC CONTOUR. CONTOUR INTERVAL 50 FEET. DASHED WHERE APPROXIMATELY LOCATED. DATUM IS MEAN SEA LEVEL

SALT DOME SHOWING LOCATION OF -2000FT. MSL CONTOUR ON SALT SURFACE

INDICATES SURFACE DRAINAGE DIVIDE

10 0 10 MILES

14 0 14 KILOMETERS

INTERPRETED BY KREITLER, 1978

PREPARED BLG DATE [illegible]
REVISED CP DATE 11/[illegible]
REVISED ______ DATE ______
APPROVED MF DATE 9/15/[illegible]

T-1035-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

POTENTIOMETRIC SURFACE OF THE WILCOX-CARRIZO AQUIFER

JOB NO. MV9600 FIGURE NO. 8-6

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219

of a potentiometric surface map for this aquifer. The Sparta Formation is not areally extensive in the study area (see Figure 8-3). Where present, its potentiometric surface is topographically controlled.

According to Peckham and others (1963), there appears to have been no lowering of water levels for aquifers within the study area, although minor seasonal fluctuations occur. BEG (written communication, 1980) does not report any significant decline in water levels since Peckham's report.

8.2.3 WATER CHEMISTRY: Surface-water chemical data for the Trinity River Basin have been studied. These data consisted of chemical analyses of samples collected from 22 surface-water and water-quality monitoring stations maintained by USGS in cooperation with the Texas Water Development Board (Hughes and Leifeste, 1965).

Surface water in the Trinity River Basin is mostly a calcium bicarbonate type (the principal ions in solution being calcium and bicarbonate). The total concentration of dissolved solids in the water is generally less than 500 mg/l (500 ppm), although concentrations exceeding 1,000 mg/l (1,000 ppm) are common and a few exceed 10,000 mg/l (10,000 ppm). Unlined storage pits for the disposal of saline water that may leak into creeks in the study area, as well as sewage effluent during low-flow periods discharged into streams, may also account for the high total dissolved-solids content values reported. The pH of the surface water in the basin tends to be slightly alkaline in the major streams and slightly acidic in creeks and small tributaries.

Sodium bicarbonate and sodium chloride water was frequently encountered at various times during the year at most locations. These water types tended to occur principally during low-flow periods of August and September, when base flow is a significant amount of the total flow in streams. Discharge of sodium bicarbonate and sodium chloride water by aquifers to streams contributes to the tendency of surface-water chemistry to change seasonally. In addition, Hughes and Leifeste (1965) state that, for portions of the Trinity River, sewage effluent from various municipalities constitutes a higher proportion of the flow during low-flow periods. This condition also contributes to a seasonal change in surface-water chemistry.

Ground-water chemistry data for samples from 415 wells in and around the study area have been retrieved from the Texas Natural Resource Information System (TNRIS) and studied. Preliminary results of analyses by BEG of more than 800 ground-water samples in the East Texas Salt Basin have also been studied. These data provide good coverage for the Wilcox aquifer, fair coverage for the Carrizo aquifer, and sparse coverage for the Queen City and Sparta aquifers.

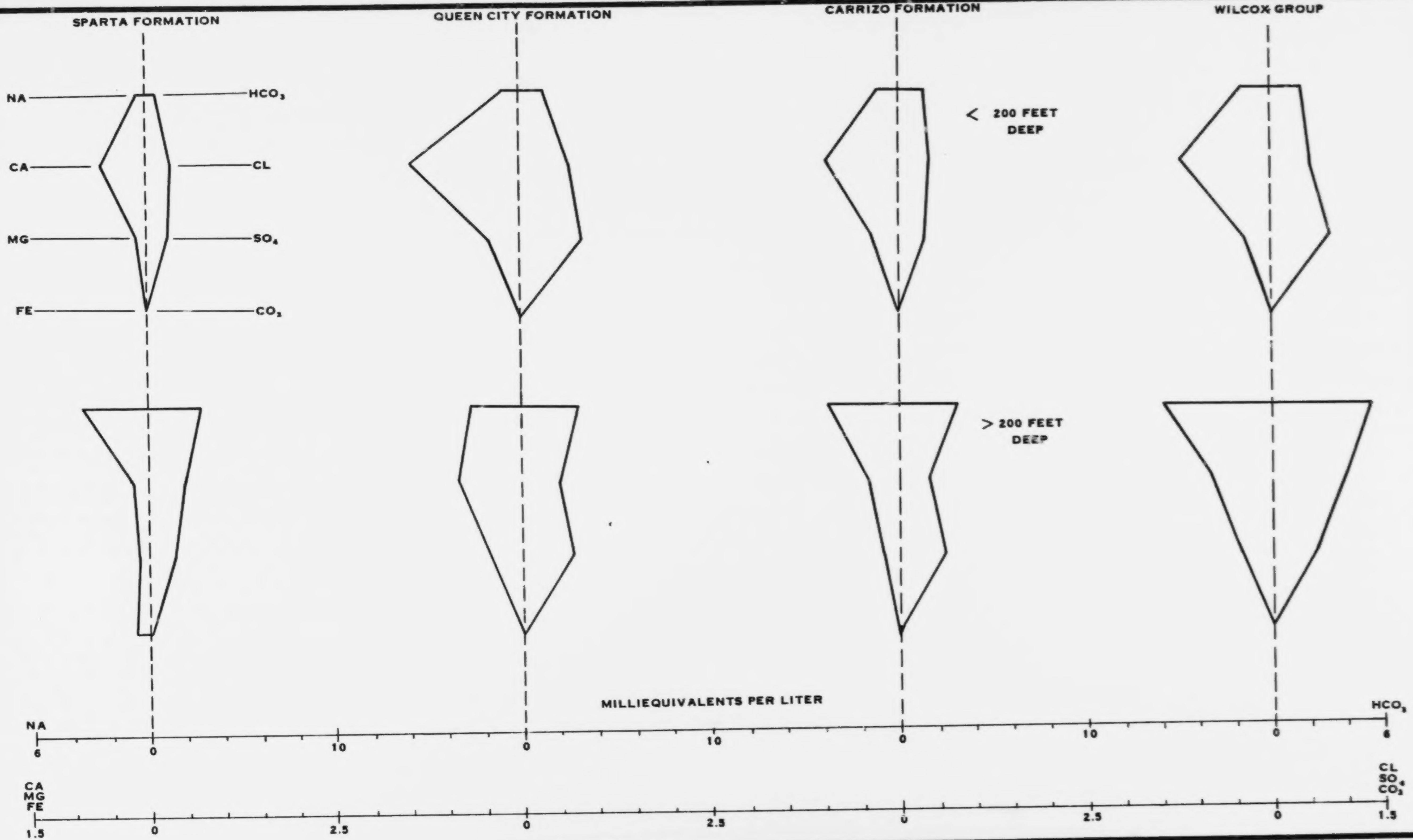
Ground water in outcrop areas of aquifers, to depths of 30 to 61 meters (100 to 200 ft), is mostly calcium bicarbonate water (Figure 8-7). This water generally has had the shortest contact time with the surrounding geologic environment and it is therefore least mineralized; however, local exceptions are numerous. Sodium chloride water is the most common exception, probably because of leakage from unlined holding ponds, spills, or improper disposal of brines from oil field operations.

Ground water from the Sparta Formation is mostly a dilute calcium bicarbonate type to depths below land surface of about 30 meters (100 ft), and mostly a sodium bicarbonate type at depths greater than 30 meters (100 ft) (Figure 8-7). Total dissolved solids tend to increase with depth from 200 mg/l (200 ppm) or less in near-surface portions of the aquifer to approximately 800 mg/l (800 ppm) in deeper portions. Locally, the water may be high in chloride and total dissolved solids, indicating contamination from cultural activities. The iron content frequently exceeds safe drinking-water standards.

The ratios of sodium to calcium and sodium to magnesium increase with depth in the Sparta Formation. Krietler and Fogg (written communication, 1980) report an increase in pH, sodium, and bicarbonate with depth for the Sparta and Queen City aquifer systems.

Ground water from the Wilcox Group is a mix of calcium bicarbonate and sodium bicarbonate water to depths of approximately 91 meters (300 ft). Below 91 meters (300 ft) the ground water is mostly a sodium bicarbonate type. Sulfate concentration decreases with depth in the Wilcox aquifer. The ratio of sodium to calcium and sodium to magnesium increases with depth in the aquifer, as does pH. More than 80 wells in the Wilcox Group, screened at depths of less than 30 meters (100 ft), had high chloride content, indicating contamination from cultural activities. Also, the concentration of iron frequently exceeds safe drinking water standards in this aquifer. Total dissolved-solids concentration is generally less than 400 mg/l (400 ppm).

[redacted]



UNLESS OTHERWISE NOTED TOP FIGURE DESIGNATES MEAN VALUES FOR WELLS LESS THAN 100 FEET DEEP, AND BOTTOM FIGURE DESIGNATES MEAN VALUES FOR WELLS GREATER THAN 100 FEET DEEP.

DATA OBTAINED FROM TEXAS WATER ORIENTED DATA BANK OF THE TEXAS WATER DEVELOPMENT BOARD AND GUYTON AND OTHERS, 1972.

PREPARED RCM DATE 8/15/80
REVISED OY DATE 11/17/81
REVISED DATE
APPROVED DATE 8/15/80
T-1429-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
MEAN CHEMICAL CHARACTERISTICS
OF GROUND WATER IN
THE FRESH WATER AQUIFER SYSTEM

JOB NO. MV9600 FIGURE 8-7

BEST DOCUMENT AVAILABLE

In portions of the study area the base of the Wilcox Group also represents the approximate base of fresh water; however, sodium chloride waters in these areas are not uncommon.

Available ground-water chemistry data are sparse for the Nacatoch Formation, the Eagle Ford Group, and the Woodbine Group. Existing data indicate ground water in these lithologies is a sodium chloride type (Figure 8-8). Total dissolved-solids concentrations range from 16,000 to >100,000 mg/l (16,000 to >100,000 ppm) (Core Labs, 1972).

There is a sequential change from calcium bicarbonate to sodium bicarbonate to sodium chloride water with increasing depth in the study area. This change is consistent with diagenetic models illustrating the chemical evolution of ground water (Chebotarev, 1955; Schoeller, 1959; Parker, 1969; Domenico, 1972; Freeze and Cherry, 1979). The increase in the ratio of sodium to calcium and the total dissolved-solids concentration with depth are indicative of either less or slower interaction with surface and near-surface waters.

Krietler and Fogg (written communication, 1980) noted spatial changes in water chemistry in the Wilcox aquifer. They reported a change from calcium bicarbonate water at the outcrop to sodium bicarbonate water downdip. They also noted an increase in pH and in sodium and bicarbonate downdip from the outcrop area. They suggest that, as ground water moves downdip through the aquifer, calcium and magnesium are replaced by sodium in the process of cation exchange. The loss of calcium causes undersaturation in the water with respect to calcite. Subsequent

[redacted]

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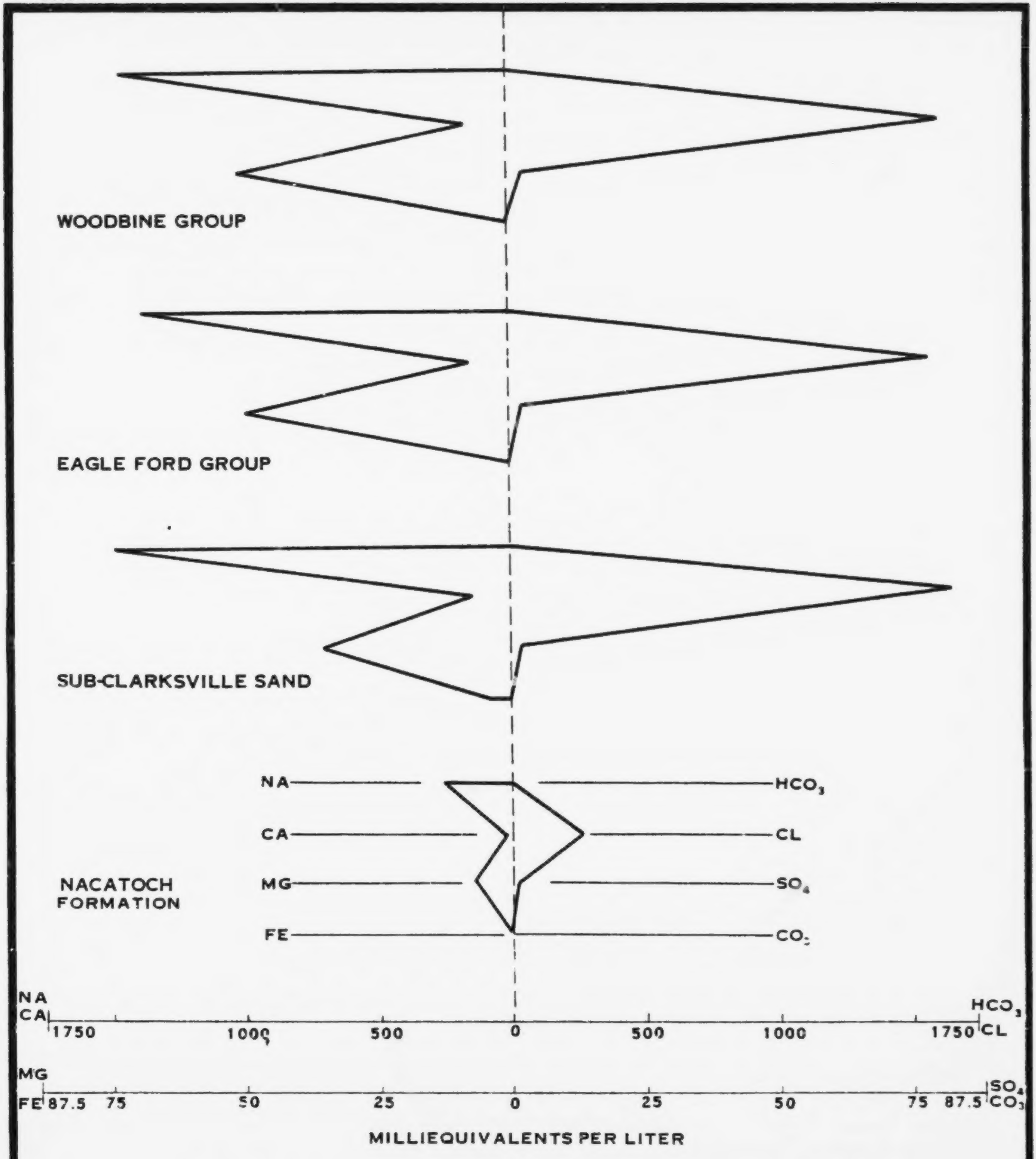


DATA FROM CORE LABORATORIES, 1972

PREPARED RSM DATE [illegible]
REVISED [illegible] DATE [illegible]
REVISED ______ DATE ______
APPROVED [illegible] DATE [illegible]
T-1428-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
MEAN CHEMICAL CHARACTERISTICS OF GROUND WATER UNDERLYING THE FRESH WATER AQUIFER SYSTEM
JOB NO. MV9600 FIGURE 8-8

BEST DOCUMENT AVAILABLE

dissolution of calcite from the cement and matrix material in the sediments, through which the ground water flows, accounts for the elevated pH.

Similar spatial changes in water chemistry were noted in the Sparta, Queen City, and Carrizo aquifers during this investigation. The model suggested by Krietler and Fogg (written communication, 1980) for describing changes in the Wilcox aquifer is probably applicable to describing trends in other fresh-water aquifers in the study area.

Temperature data from 158 well logs for wells in and near the study area have been examined (Law Engineering Testing Company, 1980). These data indicate a geothermal gradient of 0.89 C (1.61 F) per 30 meters (100 ft) of depth for basin sediments.

8.2.4 RELATIONSHIP OF SURFACE WATER TO GROUND WATER: The base flow of streams in the study area is sustained by ground water draining from the Wilcox-Carrizo, Sparta, and Queen City aquifers and from alluvial-fill deposits along the Trinity River and its tributaries. Quantitative measurements for stream flow in the study area to determine flow have not been made.

8.2.5 WATER AND AQUIFER USE: Ground water and surface water are used for a variety of industrial, agricultural, and municipal purposes throughout the study area. The heaviest use of water occurs in Freestone County where large quantities of surface water irrigate farmland. Ground-water usage is heaviest in

Anderson County. A summary of water use by county in 1974 is listed in Table 8-2.

The ground-water reservoir is stressed by pumping and injection wells. Knowledge of the location and distribution of these stresses is important because they alter ground-water flow patterns.

Largest ground-water withdrawals occur in southern Anderson County, south of Palestine, Texas (Figure 8-9). Most withdrawals are from the Wilcox-Carrizo aquifer system.

For the period of 1955 to 1976, no appreciable increase in ground-water withdrawals is discernible from water-use trends. Increased utilization of surface water and the slowdown in industrial activity, particularly oil and gas production from the East Texas Oil Fields, has contributed to the reduced growth in demand for ground-water supplies (BEG, written communication, 1980).

A total of 191 disposal wells were identified in the study area (Law Engineering Testing Company, 1978). The largest concentration of these wells is located in southern Anderson County. Injection is generally into the beds of the Wilcox and Woodbine Groups and the Carrizo Formation. Approximately 60 percent of the disposal wells return fluids to the same formation from which they were withdrawn. Figure 8-10 shows the general location of disposal wells in the study area. Information contained in disposal well permits for which data are available is summarized in the East Texas Study Area Appendix. Thirty-seven of the 191 disposal wells are located outside of the study area and are not shown in Figure 8-10.

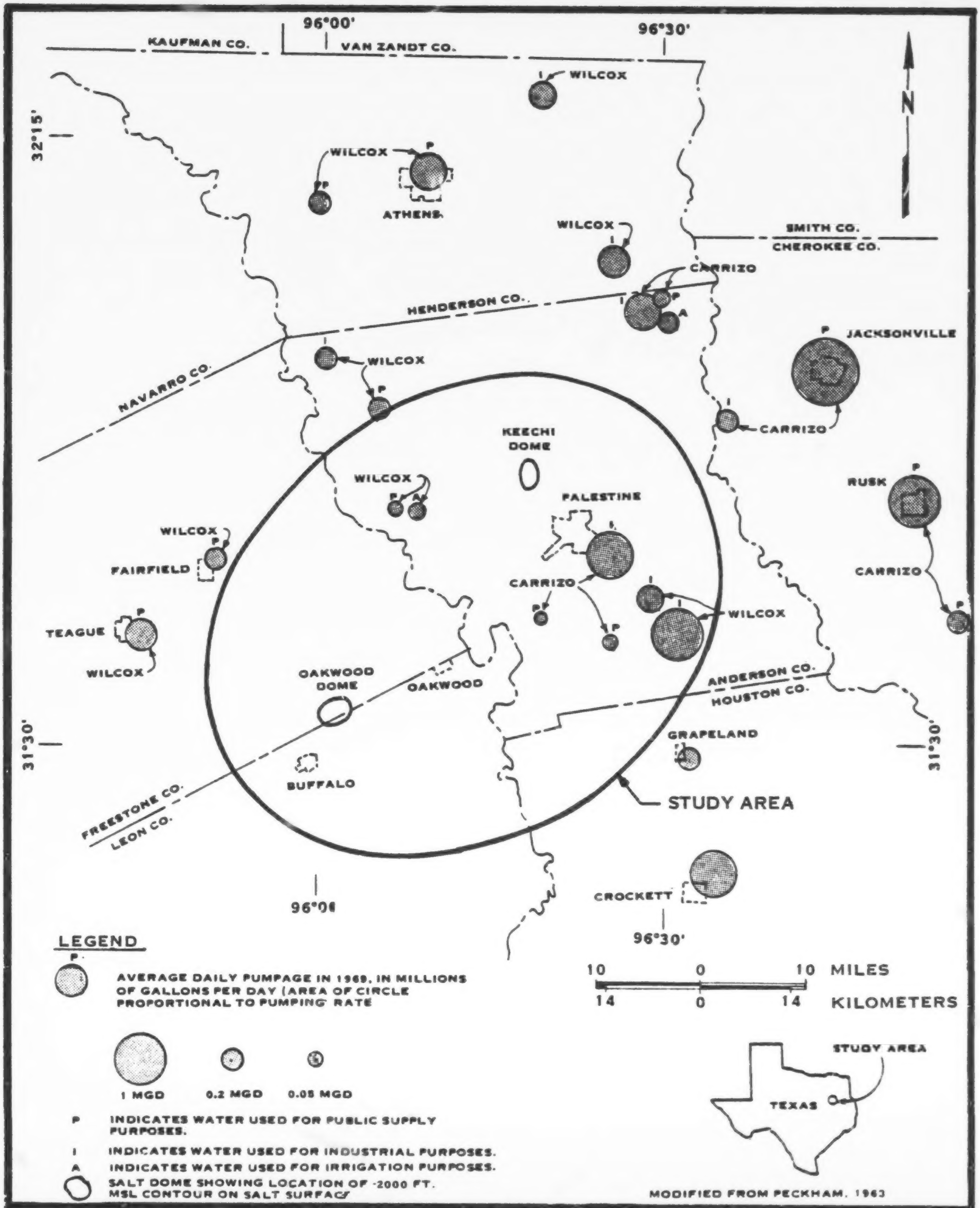
TABLE 8-2. SUMMARY OF WATER USE IN THE EAST TEXAS STUDY AREA, 1974 (million gallons per day)*

County	Ground Water	Surface Water	Total
Anderson	5.8	3.7	9.5
Freestone	1.2	13.5	14.7
Houston	2.1	4.2	6.3
Leon	1.3	1.6	2.9
TOTAL	10.4	23.0	33.4

Source: BEG, Written Communication, 1980

*To convert gallons to liters, multiply by 3.785.

[redacted]


96°00'
96°30'
KAUFMAN CO.
VAN ZANDT CO.
32°15'
WILCOX
WILCOX
P
P
ATHENS
WILCOX
I
SMITH CO.
CHEROKEE CO.
CARRIZO
HENDERSON CO.
P
A
I
JACKSONVILLE
NAVARRO CO.
WILCOX
CARRIZO
KEECHI DOME
WILCOX
P
A
RUSK
PALESTINE
WILCOX
FAIRFIELD
CARRIZO
CARRIZO
WILCOX
TEAGUE
WILCOX
OAKWOOD DOME
OAKWOOD
ANDERSON CO.
HOUSTON CO.
31°30'
31°30'
GRAPELAND
BUFFALO
STUDY AREA
FREESTONE CO.
LEON CO.
CROCKETT
96°00'
96°30'
LEGEND
AVERAGE DAILY PUMPAGE IN 1969, IN MILLIONS OF GALLONS PER DAY (AREA OF CIRCLE PROPORTIONAL TO PUMPING RATE
1 MGD
0.2 MGD
0.05 MGD
P INDICATES WATER USED FOR PUBLIC SUPPLY PURPOSES.
I INDICATES WATER USED FOR INDUSTRIAL PURPOSES.
A INDICATES WATER USED FOR IRRIGATION PURPOSES.
SALT DOME SHOWING LOCATION OF -2000 FT. MSL CONTOUR ON SALT SURFACE
10 0 10 MILES
14 0 14 KILOMETERS
N
STUDY AREA
TEXAS
MODIFIED FROM PECKHAM, 1963

PREPARED [illegible] DATE [illegible]
REVISED [illegible] DATE [illegible]
REVISED ______ DATE ______
APPROVED [illegible] DATE [illegible]

T-1422-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM.

GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA

LOCATION OF SELECTED HIGH-CAPACITY WATER SUPPLY WELLS

JOB NO. MV9600 FIGURE 8-9

BEST DOCUMENT AVAILABLE [redacted] 229

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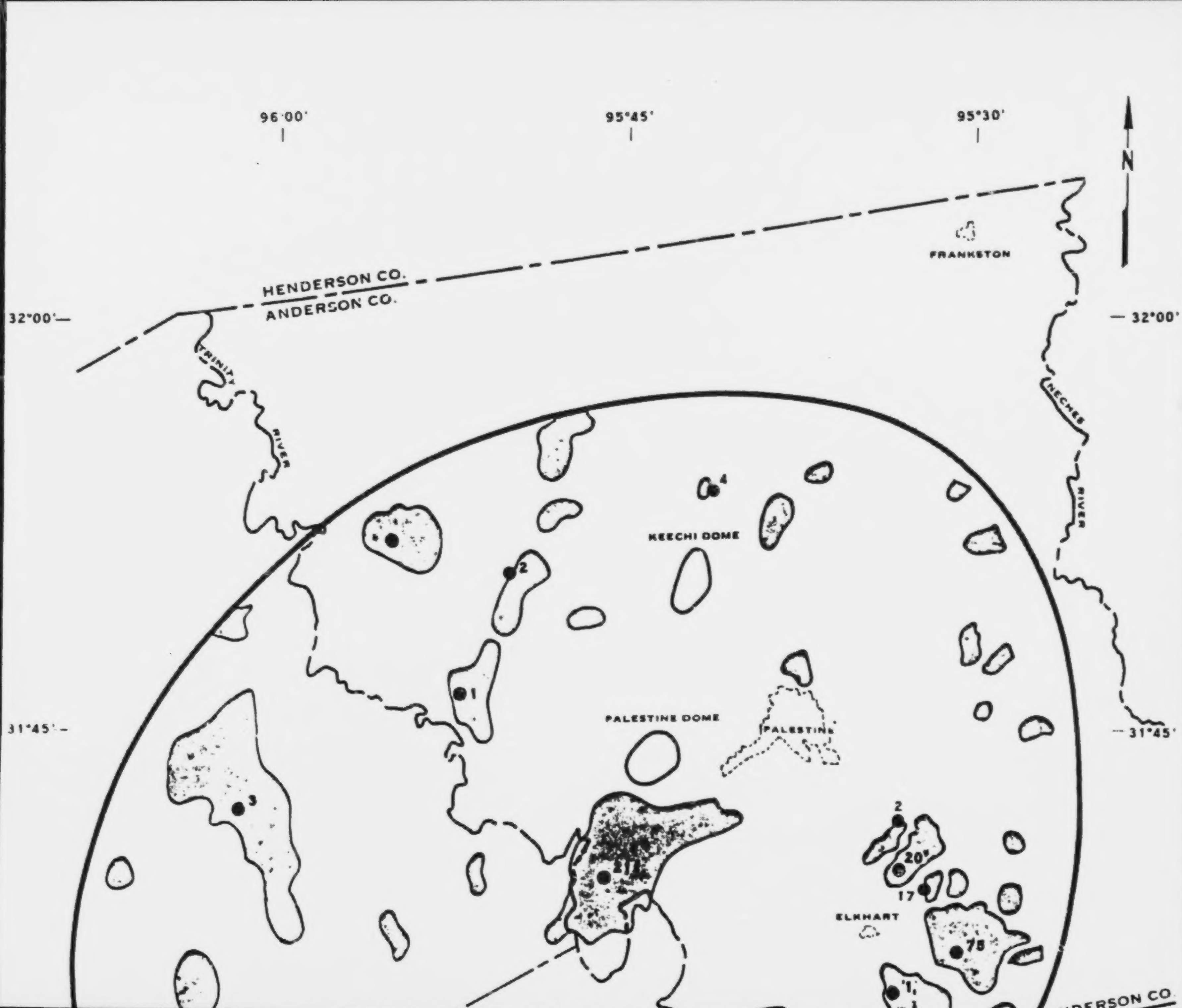
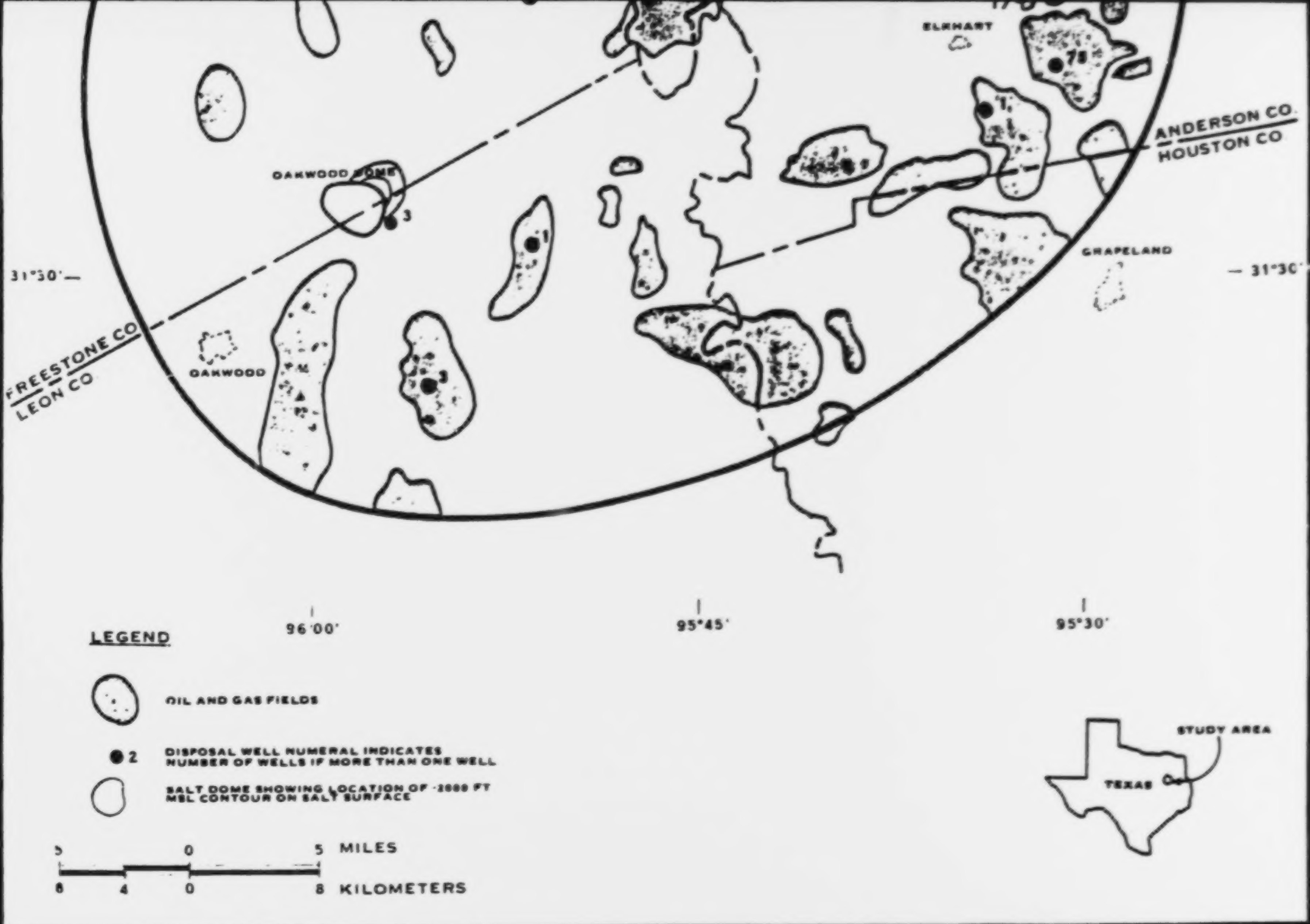
230


96°00'
95°45'
95°30'
N
HENDERSON CO.
ANDERSON CO.
FRANKSTON
32°00'
32°00'
TRINITY RIVER
NECHES RIVER
4
KEECHI DOME
2
1
PALESTINE DOME
PALESTINE
31°45'
31°45'
3
21
2
20
17
ELKHART
75
1
1
ANDERSON CO.

BEST DOCUMENT AVAILABLE

230A


ELKHART
78
7
3
1
3
OAKWOOD DOME
ANDERSON CO.
HOUSTON CO
GRAPELAND
31°30'
31°30'
FREESTONE CO
LEON CO
OAKWOOD
96°00'
95°45'
95°30'
LEGEND
OIL AND GAS FIELDS
2
DISPOSAL WELL NUMERAL INDICATES NUMBER OF WELLS IF MORE THAN ONE WELL
SALT DOME SHOWING LOCATION OF -2000 FT MSL CONTOUR ON SALT SURFACE
5 0 5 MILES
8 4 0 8 KILOMETERS
STUDY AREA
TEXAS

PREPARED	FH	DATE	
REVISED		DATE	
REVISED		DATE	
APPROVED	J Kip	DATE	11/17/81

T-1421-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

LOCATION OF DISPOSAL WELLS

JOB NO. MV9600

FIGURE 8-10

FIGURE 8-10

8.3 HYDROLOGIC CHARACTERIZATION OF SELECTED SALT DOMES IN THE EAST TEXAS STUDY AREA

The hydrology in the vicinity of Oakwood, Keechi, and Palestine Domes is described to the extent possible by using data acquired from a limited field data-collection program and from information supplied to LETCo by BEG and USGS.

8.3.1 PALESTINE SALT DOME: The Palestine Salt and Coal Company used brine wells to mine salt from the Palestine Dome during the period 1904-1937. Fifteen karst-type sinkhole features over Palestine Dome have been attributed to the salt brining operation. At least three sinks have occurred since the brining operations ended. One of these collapses is known to have occurred as late as 1979 (BEG, written communication, 1980). BEG concluded from a study of the area that:

(1) Salt dissolution of Palestine Dome is continuing
(2) The abandoned brine wells and solution cavities have created effective pathways for ground-water flow
(3) It is impossible to predict where future land collapses and accelerated rates of salt dissolution will occur
(4) Palestine Dome is an unsuitable candidate for nuclear waste disposal.

These conclusions were reached early in the Area Characterization studies, and ONWI decided that continued expenditures at Palestine Dome were not warranted. As a result, drilling and aquifer testing were not initiated.

8.3.2 OAKWOOD SALT DOME: Data for hydrologic analyses are available from a limited field data-collection program (Figures 7.1 and 8.2). Additional data are available from the literature and from state and federal agencies.

8.3.2.1 Surface-Water Hydrology: Oakwood Salt Dome is located on the Freestone-Leon County line in the Upper Keechi Creek watershed, a tributary to the Trinity River (Figure 8-2). The watershed drains an area of 1,321 km^2 (510 mi^2). Upper Keechi Creek watershed is characterized by gently rolling to hilly topography. Surface elevations in the watershed vary from +49 to +168 meters (+160 to +550 ft) MSL. The drainage pattern is predominantly dendritic, with streambed slopes varying from greater than 0.9 m/km (5 ft/mi) in the headwaters to about 0.2 m/km (1.3 ft/mi) near the mouth. The mean annual precipitation of the Upper Keechi Creek watershed is 1,016 mm (40 in) (Peckham and others, 1963).

Alligator Creek and Mustang Creek, two second-order tributaries to Upper Keechi Creek, drain the Oakwood Dome site (Figure 8-11). Both creeks discharge to Buffalo Creek, which meets Upper Keechi Creek approximately 29 km (18 mi) downstream from the dome area. Alligator Creek and one of its unnamed tributaries drain the majority of the site area. Elevations in the Alligator Creek watershed vary from +70 to +166 meters (+230 to +545 ft) MSL. Stream bed slopes vary from greater than 9 m/km (50 ft/mi) in the headwaters to approximately 2 m/km (10 ft/mi) through a series of swamps near its mouth. The drainage area of the Alligator Creek watershed is 41 km^2 (16 mi^2).

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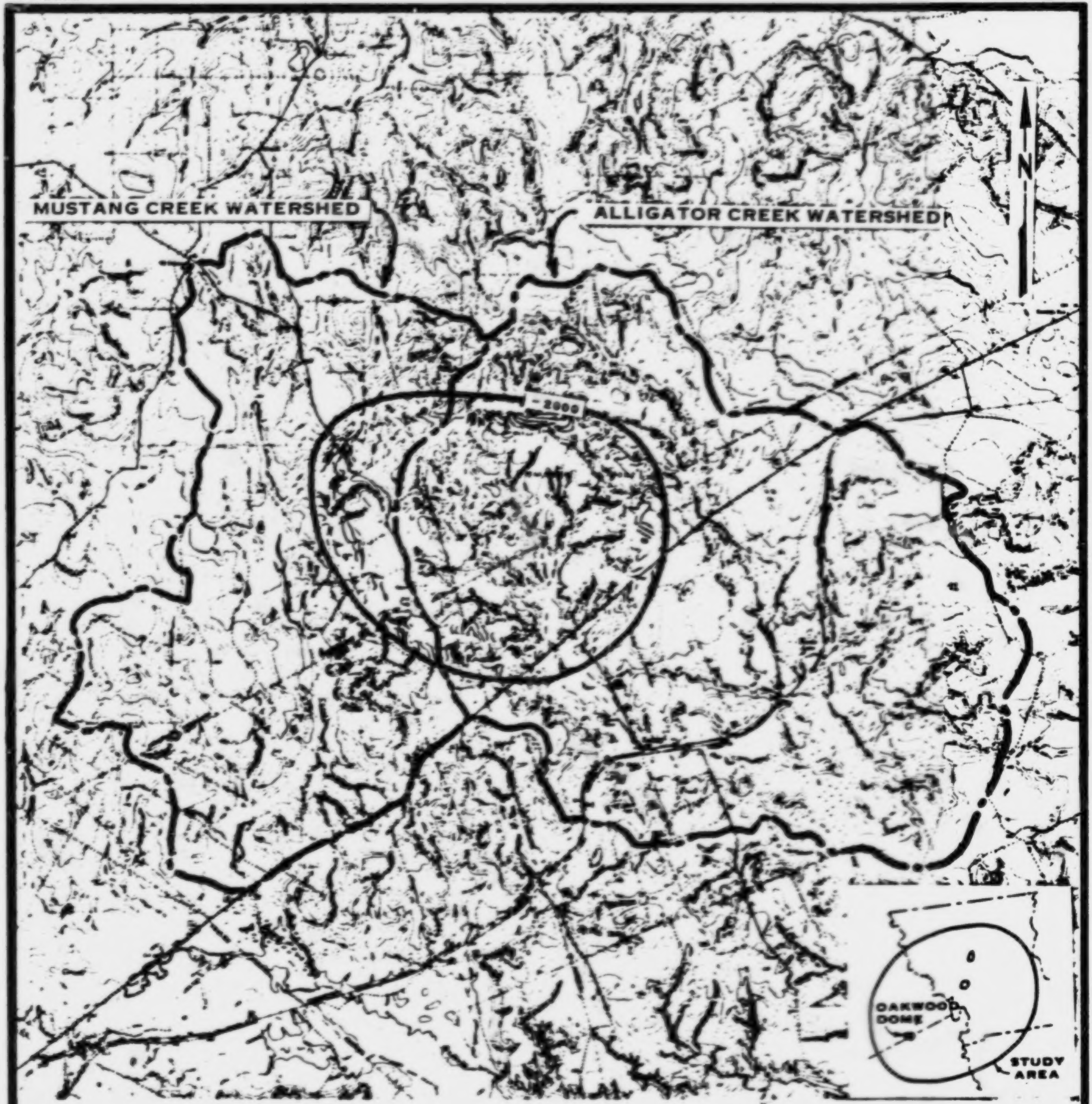

MUSTANG CREEK WATERSHED
ALLIGATOR CREEK WATERSHED
N
-2000
OAKWOOD DOME
STUDY AREA

LEGEND

— — — SURFACE DRAINAGE DIVIDE

— -2000 — LINE OF APPOXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL

1 0 1 MILES

1000 0 1000 METERS

BASE FROM U.S. GEOLOGIC SURVEY, 1:63,360 QUADRANGLE.

PREPARED BSM DATE 6/15/80
REVISED DWP DATE 4/17/81
REVISED ____ DATE ____
APPROVED ____ DATE 6/15/80
T-1029-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
TOPOGRAPHY AND DRAINAGE IN VICINITY OF OAKWOOD DOME
JOB NO. MV9600
FIGURE 8-11

BEST DOCUMENT AVAILABLE

Elevations in the Mustang Creek watershed vary from +75 to +158 meters (+245 to +520 ft) MSL. Stream bed slopes vary from greater than 9 m/km (50 ft/mi) in the headwaters to 2 m/km (10 ft/mi) near the mouth. The drainage area of Mustang Creek is 21 km^2 (8 mi^2).

8.3.2.1.1 Domal Area Drainage - The topography overlying Oakwood Dome is characterized by an irregular ridge of rounded hills, forming a ring that roughly corresponds to the outline of the dome. Elevation of the top of this ridge is approximately +137 meters (+450 ft) MSL on the west, south, and east sides. Within the ring is a central depression whose elevation drops as low as +91 meters (+300 ft) MSL. The ridge is breached on the southwest side of the dome site by an unnamed tributary of Alligator Creek. Drainage on the east side of the ridge is into Alligator Creek. Drainage on the west side of the ridge is into Mustang Creek.

8.3.2.1.2 Historical Floods - There are no published records of floods for the Oakwood Dome supradomal area or for Mustang or Alligator Creeks.

The only USGS gauging station in the Upper Keechi Creek watershed is Upper Keechi Creek near Oakwood, Texas (Station Number 08065200), approximately 18 km (11 mi) upstream from the confluence of Upper Keechi Creek and Buffalo Creek. Discharge records are available for this gauging station for the period since April 1962. The maximum flood recorded at this station occurred on May 16, 1965. The maximum discharge for this flood was 679,680 l/sec (24,000 ft^3/sec). The corresponding stage was +78 meters (+256 ft) MSL (USGS, 1978).

8.3.2.1.3 Flood Plain Delineation - Flood plain delineation was based on the probable-maximum flood of streams overlying the dome. The probable-maximum flood was determined using:

(1) Published probable-maximum precipitation values for the site area (Schreiner and Riedel, 1978)

(2) Estimated hydrologic response characteristics of the watershed

(3) The U.S. Department of Agriculture, Soil Conservation Services (SCS) flood routing computer program published as Technical Report No. 20 (TR-20) (SCS, 1965)

(4) The U.S. Army Corps of Engineers (COE) stream backwater profile computer program published as HEC-2 (COE, 1976).

General methodology involved the determination of peak discharges at several points on the stream channel and computation of associated water-surface profiles. Details regarding these calculations and analysis methods are presented in the East Texas Study Area Appendix.

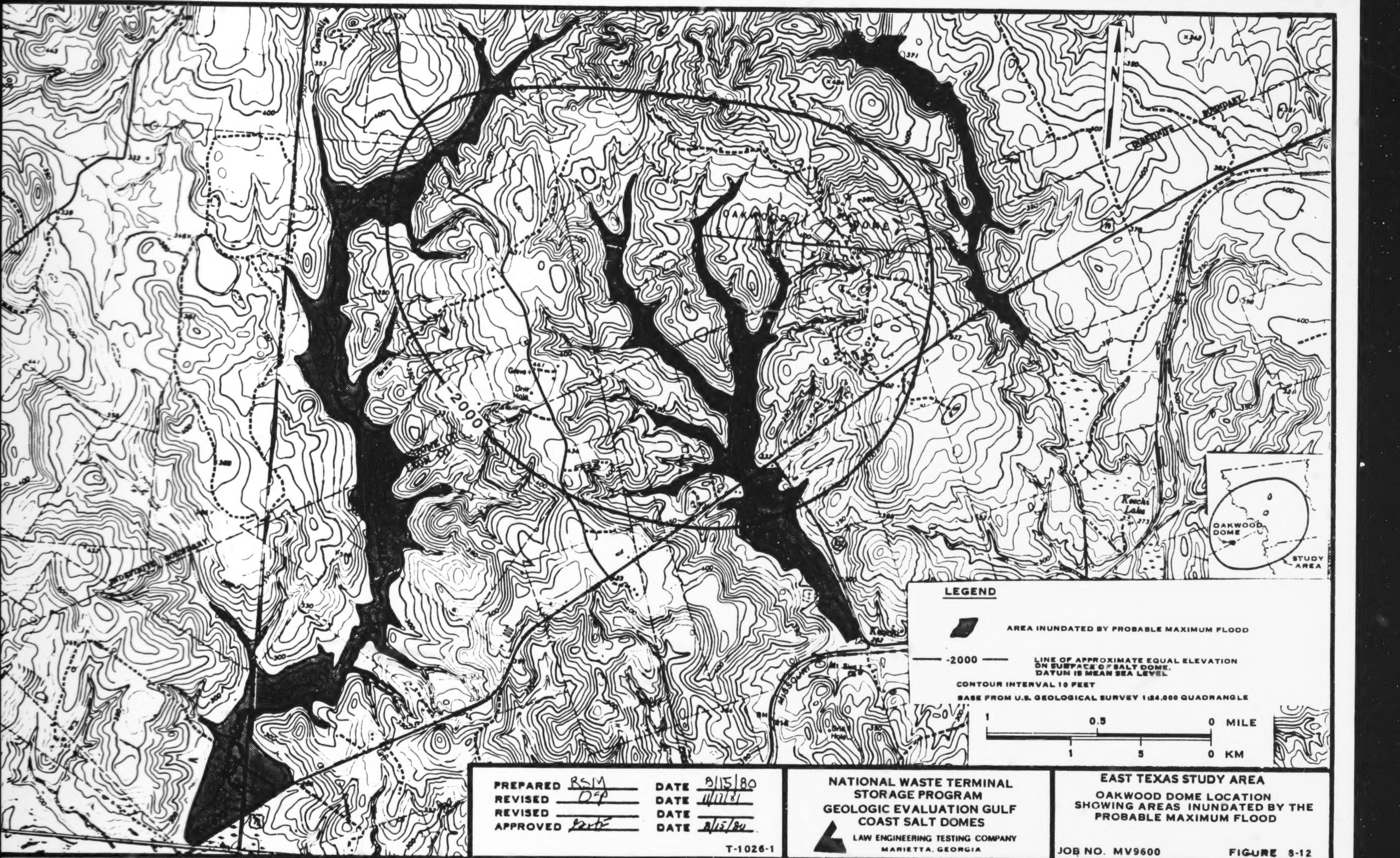
The probable-maximum flood of streams crossing the supradomal area would inundate about 89 hectares (220 acres) of the surface area projected from the -610-meter (-2,000-ft)-MSL salt dome contour. The calculated area of inundation is approximately 9 percent of the projected domal area. This postulated flooding represents the probable-maximum inundation over the Mustang Creek and Alligator Creek watersheds. The area that would be covered by the probable-maximum flood is shown in Figure 8-12.

It is unlikely that the area inundated by the probable-maximum flood would exceed that which is computed here. Parameter values not measured, but needed for inclusion in computations, were estimated to produce conservatively high volumes of runoff and stream depths.

8.3.2.2 Ground-Water Hydrology: The sequence of hydrogeologic units at Oakwood Dome is similar to that which occurs regionally. Upper Cretaceous deposits include (in ascending order) the Woodbine, Eagle Ford, Austin, Taylor, and Navarro Groups. These are overlain by Tertiary deposits which include (in ascending order) the Midway, Wilcox, and Claiborne Groups. Quaternary alluvial flood plain and terrace deposits complete the stratigraphic sequence; however, these deposits are not present everywhere over the dome.

8.3.2.2.1 Domal Area Hydrogeology - The aquifer system of principal interest in the vicinity of Oakwood Dome is composed of the entire section of Upper Cretaceous, Tertiary, and Quaternary deposits above the Woodbine Group (Figure 8-13).

The salt-caprock interface and 152 meters (500 ft) of salt were cored at Well TOG-1. In addition, a continuous core of the Wilcox Group was collected at Well TOH-2AO. All cores are being analyzed by BEG. Geophysical logs were run for all of the wells drilled.


N
OAKWOOD DOME
2000
Keechi Lake
OAKWOOD DOME
STUDY AREA
LEGEND
AREA INUNDATED BY PROBABLE MAXIMUM FLOOD
-2000
LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL
CONTOUR INTERVAL 10 FEET
BASE FROM U.S. GEOLOGICAL SURVEY 1:24,000 QUADRANGLE
1
0.5
0 MILE
1
5
0 KM

PREPARED RSM DATE 8/15/80
REVISED DP DATE 11/17/81
REVISED ______ DATE ______
APPROVED ______ DATE 8/15/80
T-1026-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

OAKWOOD DOME LOCATION SHOWING AREAS INUNDATED BY THE PROBABLE MAXIMUM FLOOD

JOB NO. MV9600

FIGURE 8-12

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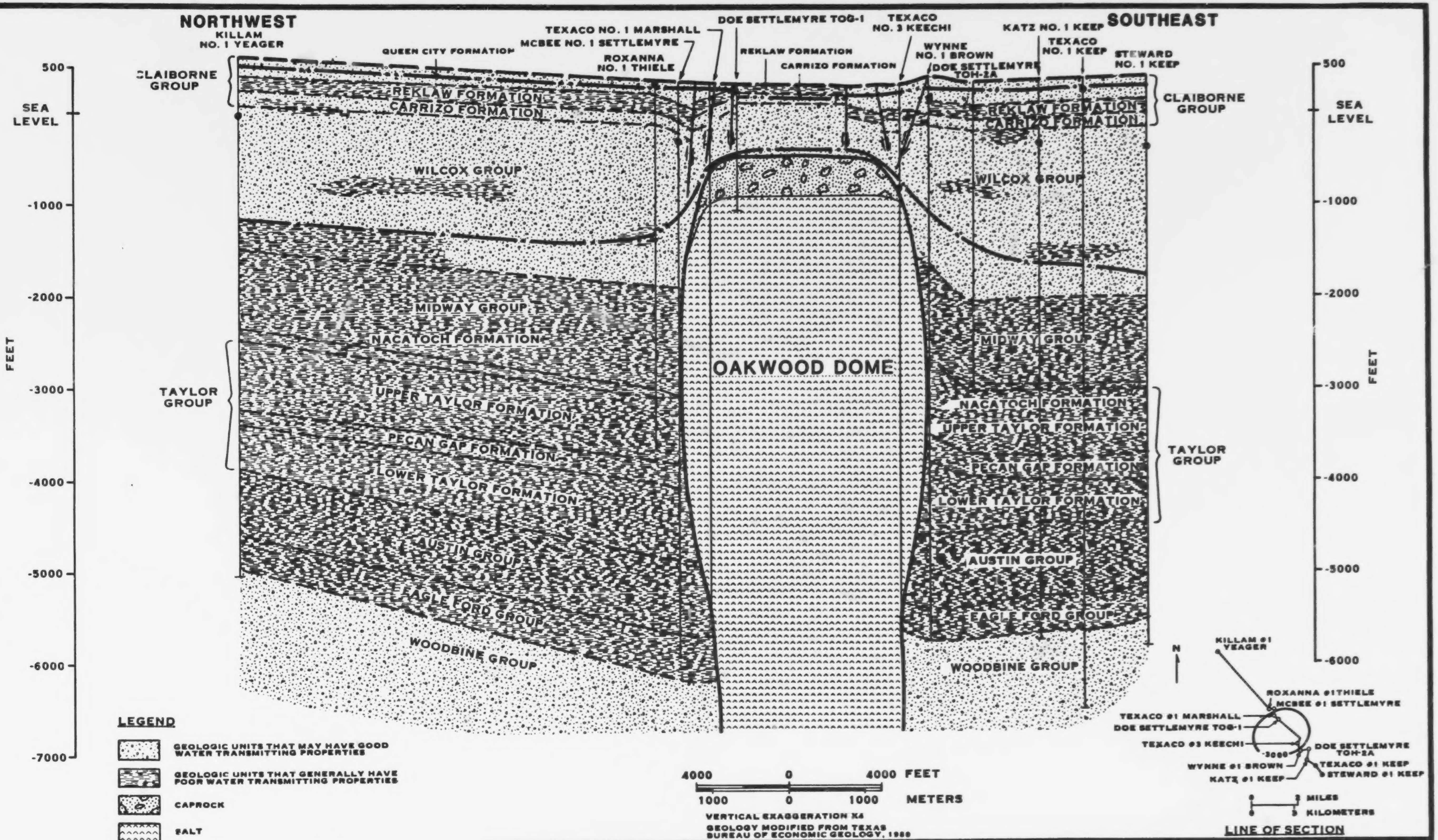
NORTHWEST
SOUTHEAST
KILLAM NO. 1 YEAGER
QUEEN CITY FORMATION
TEXACO NO. 1 MARSHALL
MCBEE NO. 1 SETTLEMYRE
ROXANNA NO. 1 THIELE
DOE SETTLEMYRE TOG-1
REKLAW FORMATION
CARRIZO FORMATION
TEXACO NO. 3 KEECHI
WYNNE NO. 1 BROWN
DOE SETTLEMYRE TOH-2A
KATZ NO. 1 KEEP
TEXACO NO. 1 KEEP
STEWARD NO. 1 KEEP
500
SEA LEVEL
-1000
-2000
-3000
-4000
-5000
-6000
-7000
FEET
CLAIBORNE GROUP
REKLAW FORMATION
CARRIZO FORMATION
WILCOX GROUP
MIDWAY GROUP
NACATOCH FORMATION
TAYLOR GROUP
UPPER TAYLOR FORMATION
PECAN GAP FORMATION
LOWER TAYLOR FORMATION
AUSTIN GROUP
EAGLE FORD GROUP
WOODBINE GROUP
OAKWOOD DOME
4000 0 4000 FEET
1000 0 1000 METERS
N
KILLAM #1 YEAGER
ROXANNA #1THIELE
MCBEE #1 SETTLEMYRE
TEXACO #1 MARSHALL
DOE SETTLEMYRE TOG-1
TEXACO #3 KEECHI
-3000
DOE SETTLEMYRE TOH-2A
WYNNE #1 BROWN
TEXACO #1 KEEP
STEWARD #1 KEEP
KATZ #1 KEEP
0 2 MILES
0 3 KILOMETERS
LINE OF SECTION
LEGEND
GEOLOGIC UNITS THAT MAY HAVE GOOD WATER TRANSMITTING PROPERTIES
GEOLOGIC UNITS THAT GENERALLY HAVE POOR WATER TRANSMITTING PROPERTIES
CAPROCK
SALT
TOP OF LOGGED INTERVAL FOR GEOLOGIC INTERPRETATION
FAULT
FORMATION CONTACT
INFERRED FORMATION CONTACT
APPROXIMATE WATER TABLE CONFIGURATION
APPROXIMATE BASE OF FRESH WATER

VERTICAL EXAGGERATION X4

GEOLOGY MODIFIED FROM TEXAS
BUREAU OF ECONOMIC GEOLOGY, 1980

PREPARED	LLK	DATE	9/30/81
REVISED	DP	DATE	11/1/81
REVISED		DATE	
APPROVED	RSM	DATE	9/28/81

T-1922-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
HYDROGEOLOGIC CROSS-SECTION
THROUGH OAKWOOD DOME

JOB NO. MV9700

FIGURE 8-13

BEST DOCUMENT AVAILABLE

Aquifer tests were completed at three sites: TOG-1, TOH-2, and TOH-5. In addition, aquifer tests were performed on nine of the eleven shallow borings over Oakwood Dome. Aquifer test results are listed in Table 8-3. Testing techniques are described in the East Texas Study Area Appendix.

Aquifer tests at Sites TOH-2 and TOH-5 were performed on wells screened in the Carrizo Formation. Results of these tests yielded average transmissivities of 167 and 260 m^2/day (1,800 and 2,800 ft^2/day) and average hydraulic conductivities of 8 and 7 m/day (26 and 24 ft/day) at Wells TOH-2D2 and TOH-5D, respectively. These values are within the range of values reported for the Carrizo aquifer.

An aquifer test performed at Well TOG-1WS yielded average transmissivity and hydraulic conductivity values of 13 m^2/day (145 ft^2/day) and 0.4 m/day (1.6 ft/day), respectively. These values are an order of magnitude less than those computed for Wells TOH-2D2 and TOH-5D.

Aquifer tests at Site TOH-2 were performed on wells screened in the Wilcox Group. Well TOH-2A was screened in the lower Wilcox Group. Average transmissivity and hydraulic conductivity values computed for the lower Wilcox were 1.4 and 0.05 m^2/day (16 and 0.6 ft/day), respectively, which are anomalously low compared to data for the Wilcox Group reported in the literature (Guyton and others, 1972; Myers, 1969; Peckham and others, 1963). The lower Wilcox Group is siltier than the upper Wilcox Group and may account for the low values. Well TOH-2AO was screened in the upper Wilcox Group. Average transmissivity and hydraulic

TABLE 8-3

SUMMARY OF AQUIFER SYSTEM PROPERTIES DETERMINED FROM DATA COLLECTION SITES

SITE ID	WELL ID	DATE OF TEST	DEPTH TO WATER PRIOR TO PUMPING (FT)	DEPTH TO WATER AT END OF TEST (FT)	PUMPING RATE (GPM)	TRANSMISSIVITY (FT^2/DAY)	HYDRAULIC CONDUCTIVITY (FT/DAY)	MAXIMUM FLUID TEMPERATURE OF PUMP DISCHARGE (°C)	AQUIFER SCREENED	METHOD OF ANALYSIS (DATA FROM ANALYSIS OF WATER LEVELS IN PUMPED WELL UNLESS OTHERWISE NOTED)
TOG-1	WS	11/15/79	61	84	46	150	1.7	21	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						140	1.6			JACOB RECOVERY
TOH-5	D	11/02/79	145	247	280	2500	21	24	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						3100	26			JACOB RECOVERY
TOH-2	A	01/29/80	88	417	28	17	0.7	34	LOWER WILCOX	MODIFIED THEIS NONEQUILIBRIUM
						13	0.6			JACOB RECOVERY
	AO	01/24/80	56	178	298	1600	16	27	UPPER WILCOX	MODIFIED THEIS NONEQUILIBRIUM
						1300	13			JACOB RECOVERY
	D2	02/07/80	97	178	313	2000	29	24	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						1500	22			JACOB RECOVERY
OK	102	03/05/80	59	81	21	176		22	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						140				JACOB RECOVERY
OK	103	02/12/80	109	116	11	575		22	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						936				JACOB RECOVERY
OK	104	02/14/80	105	134	22	298		22	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						1220				JACOB RECOVERY
OK	105	02/25/80	21	45	25	317		20	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						317				JACOB RECOVERY
OK	106	03/03/80	78	86	3	430		24	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						142				JACOB RECOVERY
OK	107	02/18/80	85	106	22	144		23	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						276				JACOB RECOVERY
OK	108	02/20/80	84	132	8	12		NA	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						12				JACOB RECOVERY
OK	115	03/12/80	30	105	6	9.0		24	CARRIZO	MODIFIED THEIS NONEQUILIBRIUM
						6.5				JACOB RECOVERY
OK	119	11/08/79	53	57	11	922		22	QUEEN CITY	MODIFIED THEIS NONEQUILIBRIUM
						1180				JACOB RECOVERY

T-1496-2

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conductivity values computed for the upper Wilcox Group were 149 m^2/day (1,600 ft^2/day) and 4 m/day (14 ft/day), respectively, which are average for values reported in the literature (Guyton and others, 1972; Myers, 1969; Peckham and others, 1963).

Water level data for the hydrologic data-collection sites at Oakwood Dome indicate hydraulic connection between the Wilcox and Carrizo aquifers. No significant differences in water levels (MSL) for these wells are discernible from the data. The water levels are nearly the same for wells screened in several different intervals in these aquifers. Water levels range from a high of +91 meters (+299 ft) MSL for a well screened in the upper part of the Carrizo aquifer to a low of +86 meters (+281 ft) MSL for a well screened in the Wilcox aquifer.

Aquifer tests were performed on the shallow borings over Oakwood Dome. These wells were intended to be used as water level and water-quality observation wells and not as aquifer test wells. These shallow borings had only 3 meters (10 ft) of screen and the entire thickness of the aquifer was not screened. This may account for the unusually low transmissivities computed for the Carrizo aquifer over Oakwood Dome. Transmissivity values range from a low of 6 m^2/day (65 ft^2/day) to a high of 113 m^2/day (1,220 ft^2/day) and average 27 m^2/day (294 ft^2/day) for all shallow boring aquifer tests. This average is below the regional aquifer transmissivity by one order of magnitude (Guyton and others, 1972; Myers, 1969; Peckham and others, 1963).

Water levels in shallow borings over Oakwood Dome were used to define the potentiometric surface of the Carrizo aquifer. As shown in Figure 8-14, the potentiometric surface of the Carrizo aquifer over Oakwood Dome is approximately +91 meters (+300 ft) MSL and follows the regional trend of potentiometric levels (see Figure 8-6). The shape of the +91-meter (+300-ft)-MSL potentiometric contour suggests that flow is generally from topographic high areas to areas of lower elevations in stream valleys. Installation of more piezometers over Oakwood Dome is necessary to define other potentiometric levels over the dome.

8.3.2.2.2 Ground-Water Flow Time Analysis - Following a report by Pacific Northwest Laboratories (1979), LETCo investigated estimated average ground-water flow times from various depths upwards to the base of the fresh-water surface at Oakwood Dome (Law Engineering Testing Company, 1981). An objective of the analysis was to ascertain if significant differences between ground-water flow times exist among the candidate domes. The desire for quantitative answers and the lack of some specific data dictated a procedure requiring a number of assumptions. These assumptions included not only a simplified model but also an empirical selection of numerical values for most of the important parameters. The most significant variable directly available from measured data is the ratio of the length of the travel path in shale or clay to the total length of the travel path. Both of these lengths were assumed to be vertical; thus the ratio, which is a function of the lithology, was obtained

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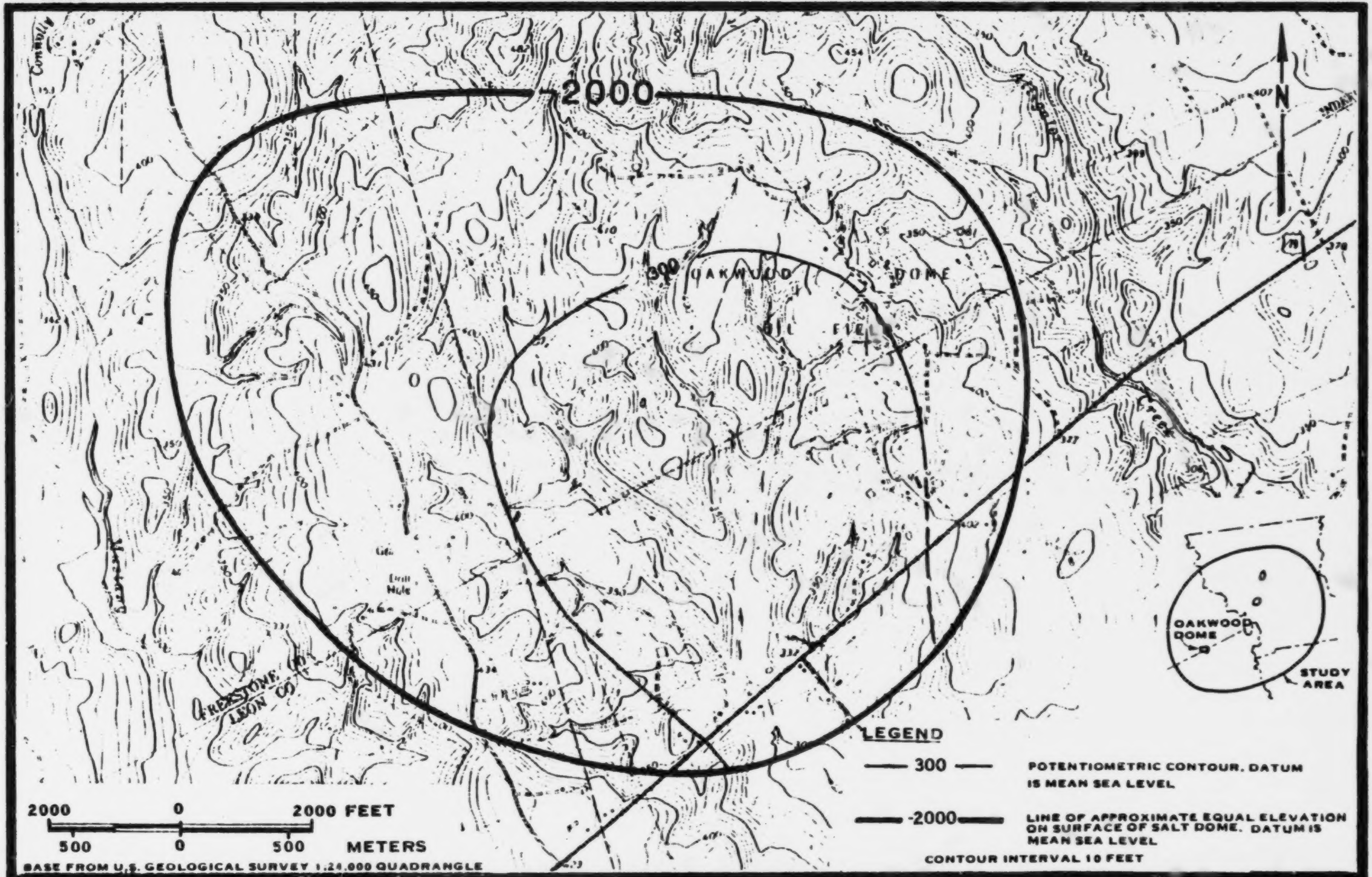
2000
300
OAKWOOD DOME
OIL FIELD
N
FREESTONE CO
LEON CO
OAKWOOD DOME
STUDY AREA
LEGEND
300 — POTENTIOMETRIC CONTOUR, DATUM IS MEAN SEA LEVEL
-2000 — LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL
CONTOUR INTERVAL 10 FEET
2000 0 2000 FEET
500 0 500 METERS
BASE FROM U.S. GEOLOGICAL SURVEY 1:24,000 QUADRANGLE

PREPARED	BSM	DATE	8/15/80
REVISED		DATE	
REVISED		DATE	
APPROVED		DATE	8/15/80

T-1427-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
POTENTIOMETRIC SURFACE OF THE CARRIZO AQUIFER OVER OAKWOOD DOME

JOB NO. MV9600 FIGURE 8-14

through geophysical log interpretation from selected holes in the dome area.

The results of the analysis indicate that the estimated average ground-water flow times are long (hundreds of years per foot of flow path), and that significant differences in these flow times among the candidate domes cannot be substantiated with the existing data. Figure 8-15 depicts the relationship between the existing average ground-water flow time and the path length from depth to the base of fresh water for both Oakwood and Keechi Salt Domes.

8.3.2.3 Water Chemistry: The chemical composition of water in the vicinity of Oakwood Dome was investigated. Surface-water chemical data collected by USGS (Yost, written communication, 1980) has been studied and integrated with ground-water chemical data retrieved from TNRIS and LETCo hydrogeologic and geologic investigation sites.

Results of USGS field measurements at 18 stream flow sites in the vicinity of the dome indicate that surface waters are acidic and low in total dissolved solids. Specific conductance of the water ranges between 150 and 700 micromhos per centimeter. Reported pH values of the water range between 3.4 and 7.4 standard units. This variability could be related to poor instrument function or to the period of time during which measurements were made; i.e. low-flow periods. The great range in pH may be significant, but more data are necessary to determine the reasons for this variability.

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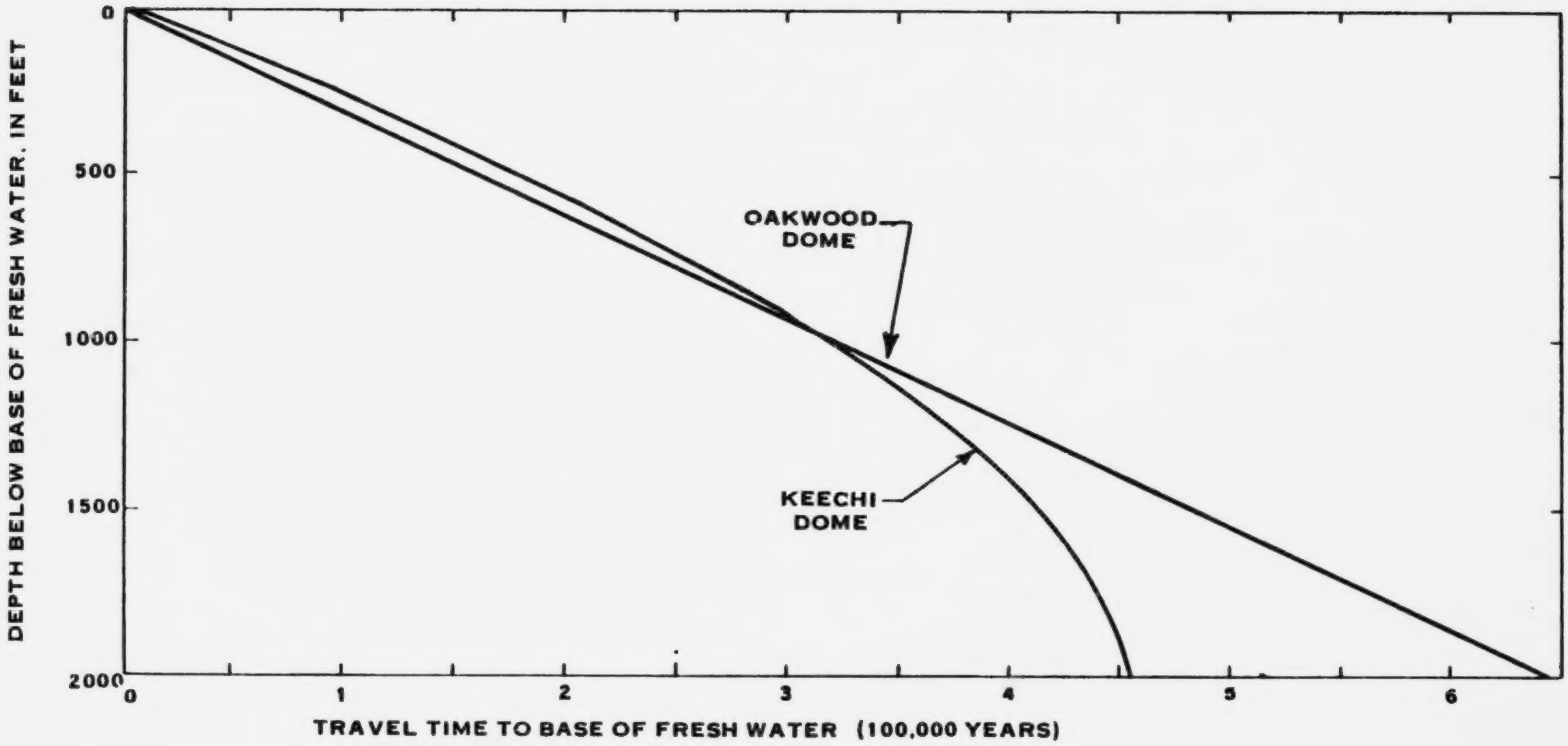

PREPARED RSM DATE 8/15/80
REVISED RP DATE 11/1/81
REVISED DATE
APPROVED DATE [illegible]
T-1036-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA

RELATION OF TRAVEL TIME ALONG A VERTICAL FLOW PATH TO DEPTH IN THE VICINITY OF CANDIDATE DOMES

JOB NO. MV9600

FIGURE 8-15

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Laboratory results for chemical analysis of water samples from 12 sites indicate surface water around the dome is a sodium sulfate chloride type. Total dissolved-solids concentration ranges between 80 and 360 mg/l (80 and 360 ppm). The water chemistry is different than that found at regional data-collection sites where surface water is generally a calcium bicarbonate type. This variability may also be significant and should be investigated.

The water chemistry of ground water in the vicinity of Oakwood Dome is similar to that encountered regionally. Generally, the water is a calcium bicarbonate or sodium bicarbonate type and is low in total dissolved solids (Table 8-4). Exceptions are noted for water collected at Hydrogeologic Test Wells TOH-2AO and TOH-2D2 (Table 8-4). Samples from these wells are bicarbonate and sulfate types, respectively. However, the results reported in Table 8-4 are questioned on the basis of chemical balance checks of the data. Additional data are needed to determine the chemistry of ground water collected from these wells.

8.3.2.4 Relationship of Surface Water to Ground Water: It is expected that base flows of streams over Oakwood Salt Dome will be lower than base flows of streams in other parts of the study area. Formations outcropping over Oakwood Salt Dome are predominantly alluvium and terrace deposits, as well as sediments of the Claiborne Group--mainly the Queen City and Reklaw Formations, with some Carrizo also present (Figure 7-7). The water-bearing and water-transmitting properties of most of these formations are

TABLE 8-4

SELECTED CHEMICAL ANALYSES OF GROUND WATER FROM GEOLOGIC AND HYDROLOGIC TEST SITES

(ANALYSES REPORTED IN MILLIGRAMS PER LITER EXCEPT AS NOTED.)

Data Source	Well	Sample Interval (ft)	Aquifer	Date of Collection	Temperature °C	Specific Conductance (micromhos)	pH (s.u.)	Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)	Dissolved solids (residue at 180°C)	Sodium dissolved (as Na)	Chloride dissolved (as Cl)	Bicarbonate (as HCO_3)	Carbonate (as CO_3)	Calcium dissolved (as Ca)	Magnesium dissolved (as Mg)	Potassium dissolved (as K)	Sulfate dissolved (as SO_4)	Sulfide dissolved (as S)	Silica dissolved (as SiO_2)	Iron, dissolved (ug/l as Fe)	Manganese dissolved (ug/l as Mn)	Nitrogen, Nitrate dissolved (as N)	Iodide dissolved (as I)	Bromide dissolved (as Br)
LETCo	TOC-18S	107-168	Carrizo	11/14/79	-	170L	-	-	50	98	10	14	-	-	0.2	2.9	1.0	46	<1.0	5	1.5	<0.1	-	<0.1	<0.1
LETCo	TOH-2A	1897-1916	Lower Wilcox	01/21/80	30	1700	8.7	553	6	872	329T	120	553	0	2.6T	0.1T	1.6T	290	<1.0	41	0.1	<0.1	<0.1	<0.1	<0.1
LETCo	TOH-2A	1897-1916	Lower Wilcox	01/22/80	32	1400	8.6	554	6	870	328T	116	554	0	2.0T	0.1T	1.0T	272	<1.0	37	0.1	<0.1	0.1N3	<0.1	<0.1
LETCo	TOH-2AO	833-935	Upper Wilcox	01/24/80	26	470	9.1	203	30	274	73T	16	203	0	11.0T	0.9T	3.6T	240	-	33	0.1T	<0.1	<0.1	-	-
LETCo	TOH-2AO	833-935	Upper Wilcox	01/25/80	27	490	8.4	200	28	282	78T	16	200	0	10.3T	0.9T	4.2T	230	-	31	1.2T	<0.1	0.2N3	-	-
LETCo	TOH-2O0	520-560	Carrizo	02/4/80	-	435	-	-	-	286	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-
LETCo	TOH-2O2	516-577	Carrizo	02/7/80	24	505	6.1	43	126	316	37T	20	43	0	29T	3.0T	7.4T	160	<1.0	33	7.1	0.1	0.1N3	<0.1	<0.1
LETCo	TOH-2O2	516-577	Carrizo	02/8/80	23	500	6.0	43	128	308	36T	20	43	0	29T	3.0T	7.2T	170	<1.0	32	6.7	0.1	0.3N3	<0.1	0.2
LETCo	TOH-3O	477-603	Carrizo	11/2/79	-	300	5.5	-	-	166	14	23	0	0	14	5	2.4	46	-	15	10	0.1	-	<0.1	<0.1

T = Total

N3 = Nitrogen as NO_3

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low. Quantitative measurements of the base flow of streams in the study area have not been made and no historical records exist.

8.3.2.5 Water and Aquifer Use: Ground-water withdrawals from the Wilcox-Carrizo aquifer in the vicinity of Oakwood Dome are small. No large cities are located near Oakwood Dome. Pumpage of water for municipal and agricultural purposes in 1960 was approximately 2.2 million l/day (0.6 million gal/day) in Leon County (Peckham, 1965) and 4.5 million l/day (1.2 million gal/day) in Freestone County in 1969 (Guyton and others, 1972). BEG (written communication, 1980) does not report any significant increase in water use in these counties (Figure 8-9).

Ground-water withdrawals from other aquifers in these counties are typical of small farm rural areas with numerous domestic and other low-yield [less than 1.2 l/sec (20 gal/min)] wells.

Three disposal wells are permitted to operate near Oakwood Salt Dome. These wells discharge saline waste into the Woodbine Group at elevations below -366 meters (-1,200 ft) MSL. Quantities of waste disposed are variable but average 261,000 barrels per year (Figure 8-10) (Law Engineering Testing Company, 1978).

8.3.3 KEECHI SALT DOME: Geologic and hydrologic data-collection sites were planned for Keechi Dome but were eliminated at the direction of ONWI prior to the initation of the field program. Therefore, analysis and discussion of the hydrology around Keechi

Dome are limited to information contained in the literature and data available from state and federal agencies.

8.3.3.1 Surface-Water Hydrology: Keechi Dome is located in the Keechie Creek watershed, a tributary to the Trinity River (Figure 8-2). The watershed is located entirely within Anderson County and drains an area of 49 km^2 (19 mi^2).

The Keechie Creek watershed is characterized by gently rolling to hilly topography. Surface elevations in the watershed vary from +61 to +219 meters (+200 to +720 ft) MSL. The drainage pattern is predominantly dendritic, with stream bed slopes varying from greater than 9 m/km (50 ft/mi) in the headwaters to approximately 2 m/km (10 ft/mi) near the mouth.

8.3.3.1.1 Domal Area Drainage - The topography overlying Keechi Dome is characterized by gently rolling hills. Keechie Creek runs almost directly down the major axis of the dome (Figure 8-16). The highest elevation on the site is approximately +149 meters (+490 ft) MSL.

8.3.3.1.2 Historical Floods - There are no published records of floods for the domal area or for Keechie Creek.

The nearest USGS gauging station is near Oakwood, Texas (Station Number 08065000), located on the Trinity River 6 km (4 mi) downstream from its confluence with Keechie Creek (Figure 8-2). Daily discharge records are available for the Oakwood gauging station for the period of October 1924 to the present. Monthly discharge records are available for the period of October 1923 to September 1924. The maximum flood at this site occurred in May 1890. The maximum discharge for this flood was 5,097,600 l/sec (180,000 ft^3/sec). The corresponding stage was +70 meters (+230 ft) MSL. This flood occurred prior to establishment of the Oakwood gauging station. The flood discharge was estimated using information reported in local newspapers (USGS, 1978).

8.3.3.1.3 Flood Plain Delineation - Flood plain delineation was based on the probable-maximum flood of streams overlying the dome. The probable-maximum flood was determined using:

(1) Published probable-maximum precipitation values for the site area (Schreiner and Riedel, 1978)

(2) Estimated hydrologic response characteristics of the watershed

(3) The U.S. Department of Agriculture, Soil Conservation Service (SCS) flood-routing computer program published as Technical Report No. 20 (SCS, 1965)

(4) The U.S. Army Corps of Engineers (COE) stream back-water profile computer program published as HEC-2 (U.S.A.C.o.E., 1976).

General methodology involved the determination of peak discharges at several points on the stream channel and computation of associated water-surface profiles. Details regarding these calculations and analysis methods are presented in the East Texas Study Area Appendix.

251

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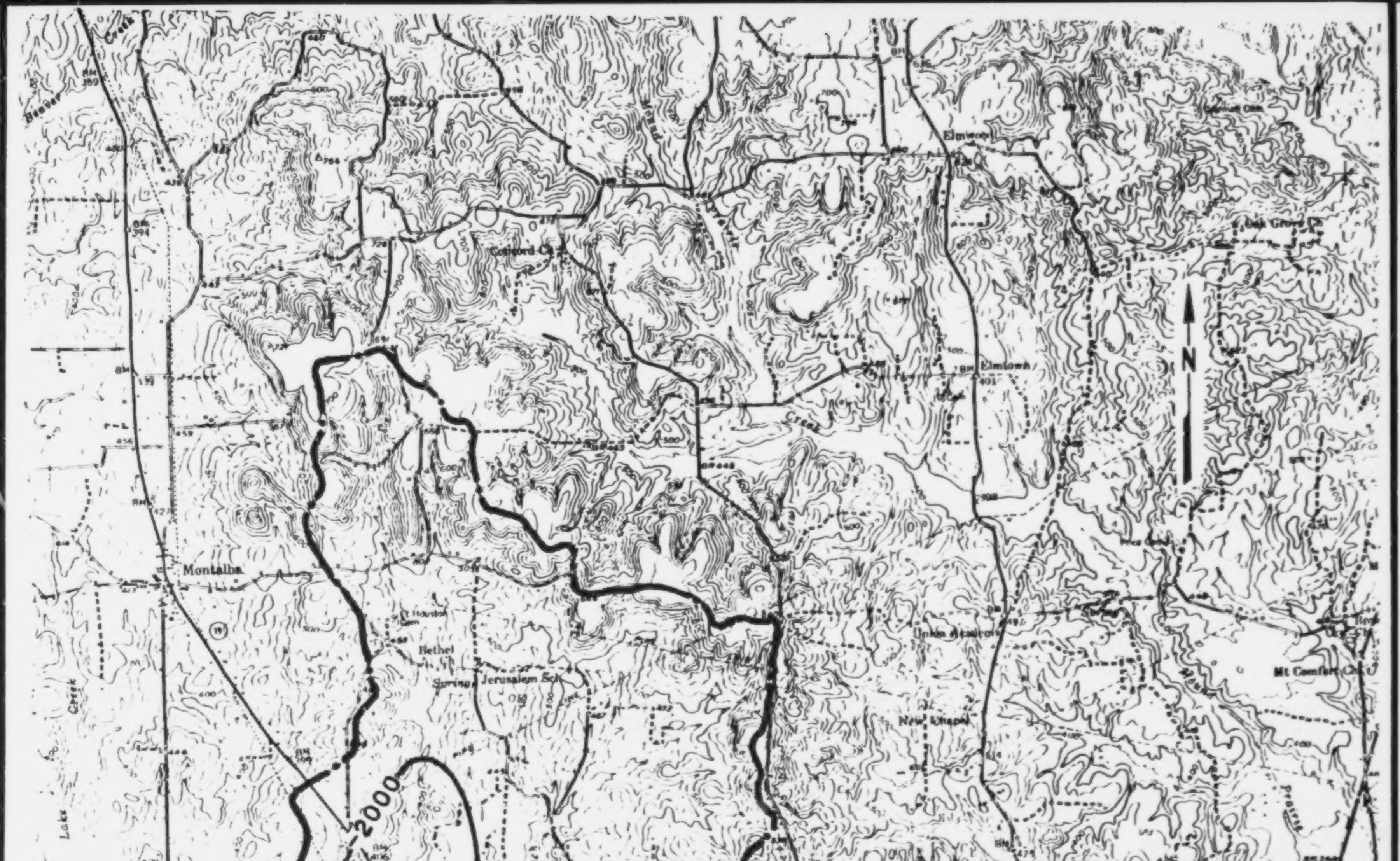

Beaver Creek
Elmwood
Concord Ch
Oak Grove Ch
N
Elmtown
Creek
Montalba
Bethel
Springs
Jerusalem Sch
Union Academy
Mt Comfort Ch
New Chapel
2000
Lake Creek
Creek
Branch
Sycamore
Foster Sch
Shiloh Ch
Caney Academy

251A

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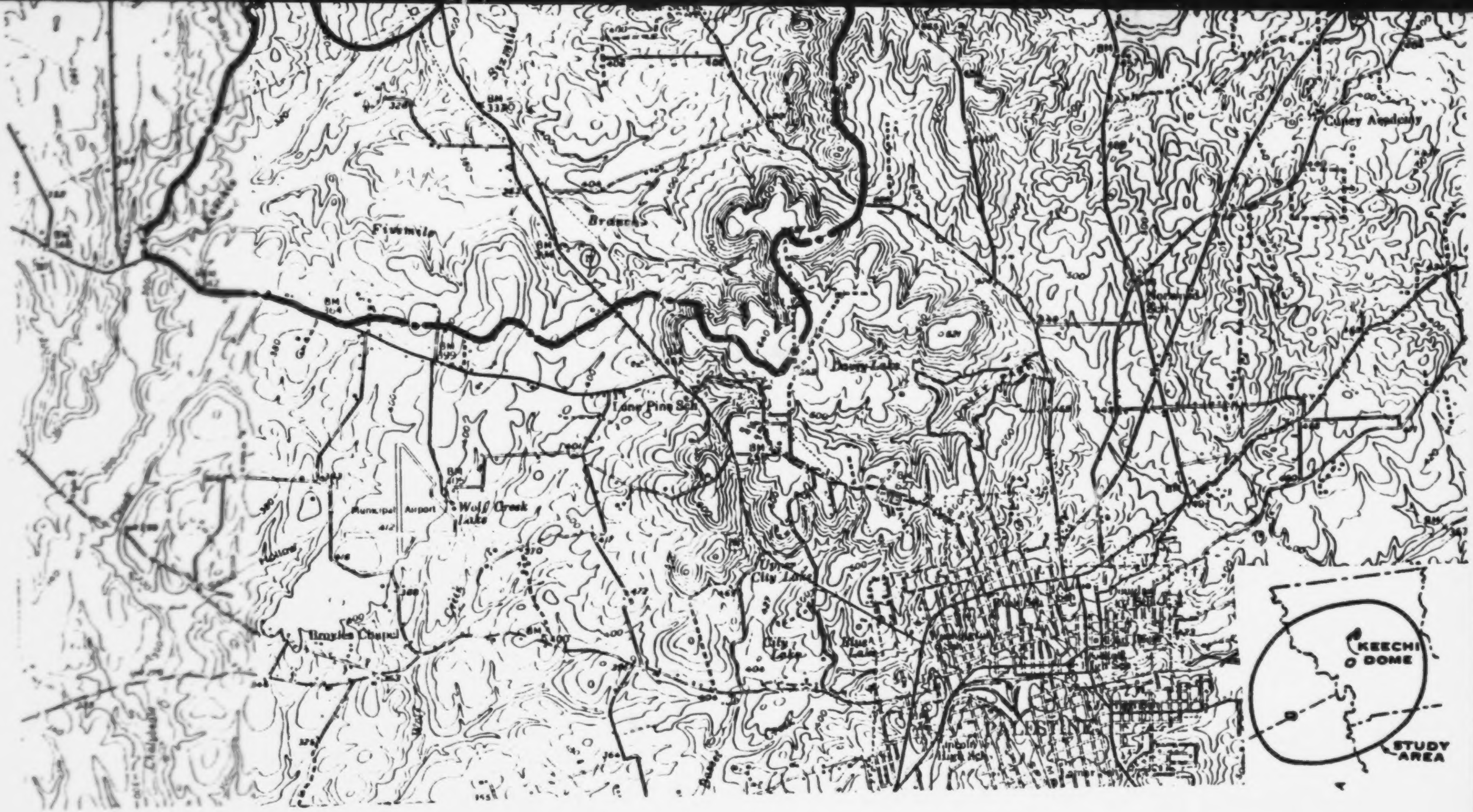
FIGURE 8-16



Fivemile
Branch
Lone Pine Sch
Municipal Airport
Wolf Creek Lake
City Lake
PALESTINE
KEECHI DOME
STUDY AREA

LEGEND

▬ ▪ ▬ SURFACE DRAINAGE DIVIDE

—2000— LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL

1 0 1 MI.

1 0 1 KM.

CONTOUR INTERVAL 20 FEET

BASE FROM U.S. GEOLOGICAL SURVEY 1:63,360 QUADRANGLE

PREPARED R&M DATE 8/15/80
REVISED DP DATE 11/17/81
REVISED DATE
APPROVED DATE 8/15/80

T-1011-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
TOPOGRAPHY AND DRAINAGE IN
VICINITY OF KEECHI DOME

JOB NO. MV9600

FIGURE 8-16

The probable-maximum flood of streams crossing the supradomal area would inundate about 85 hectares (210 acres) of the projected area above the -610-meter (-2,000-ft)-MSL salt dome contour. The inundated area is approximately 17 percent of the projected domal area. This flooding represents the probable-maximum inundation over the Keechie Creek subwatershed (Figure 8-17).

It is unlikely that the area inundated by the probable-maximum flood would exceed that which is computed here. Parameter values not measured, but needed for inclusion in computations, were estimated to produce conservatively high volumes of runoff and stream depths.

8.3.3.2 Ground-Water Hydrology: The sequence of hydrogeologic units at Keechi Dome is similar to that which occurs regionally. Upper Cretaceous deposits include (in ascending order) the Woodbine, Eagle Ford, Austin, Taylor, and Navarro Groups. These are overlain by Tertiary age deposits which include (in ascending order) the Midway, Wilcox, and Claiborne Groups. Quaternary alluvial flood plain and terrace deposits complete the stratigraphic sequence; however, these deposits are not present everywhere over the dome.

8.3.3.2.1 Domal Area Hydrogeology - The aquifer system of interest in the vicinity of Keechi Salt Dome is composed of the entire sequence of Upper Cretaceous, Tertiary, and Quaternary deposits above the Woodbine Group (Figure 8-18).

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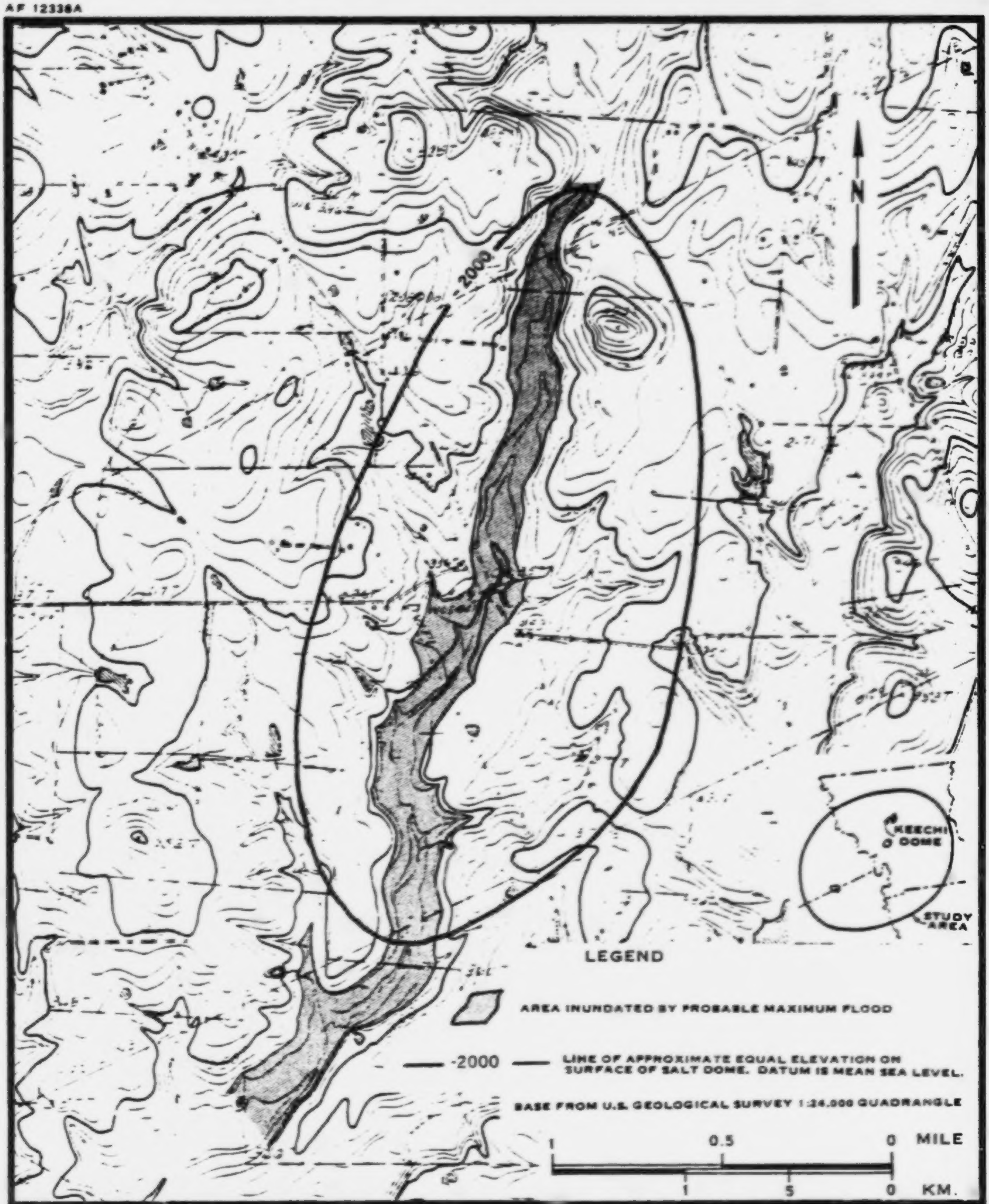
N
-2000
KEECHI DOME
STUDY AREA
LEGEND
AREA INUNDATED BY PROBABLE MAXIMUM FLOOD
-2000 LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL.
BASE FROM U.S. GEOLOGICAL SURVEY 1:24,000 QUADRANGLE
1 0.5 0 MILE
1 5 0 KM.

PREPARED ______ DATE ______
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED ______ DATE ______
T-1028-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

EAST TEXAS STUDY AREA
KEECHI DOME LOCATION
SHOWING
AREA INUNDATED BY THE
PROBABLE MAXIMUM FLOOD

JOB NO. MV9600 FIGURE 8-17

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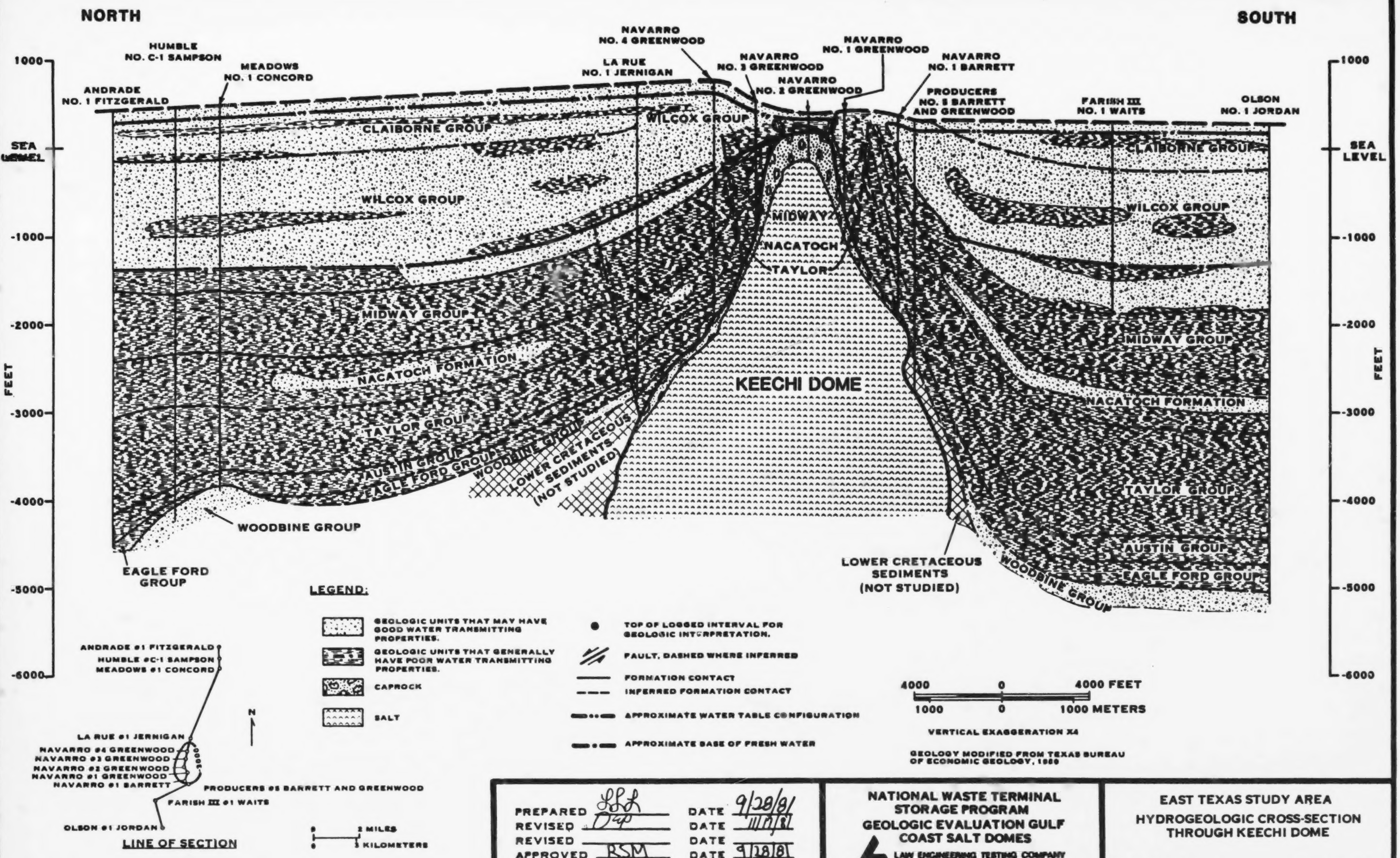
NORTH
SOUTH
HUMBLE NO. C-1 SAMPSON
MEADOWS NO. 1 CONCORD
ANDRADE NO. 1 FITZGERALD
LA RUE NO. 1 JERNIGAN
NAVARRO NO. 4 GREENWOOD
NAVARRO NO. 3 GREENWOOD
NAVARRO NO. 2 GREENWOOD
NAVARRO NO. 1 GREENWOOD
NAVARRO NO. 1 BARRETT
PRODUCERS NO. 5 BARRETT AND GREENWOOD
FARISH III NO. 1 WAITS
OLSON NO. 1 JORDAN
1000
SEA LEVEL
-1000
-2000
-3000
-4000
-5000
-6000
FEET
CLAIBORNE GROUP
WILCOX GROUP
MIDWAY GROUP
NACATOCH FORMATION
TAYLOR GROUP
AUSTIN GROUP
EAGLE FORD GROUP
WOODBINE GROUP
LOWER CRETACEOUS SEDIMENTS (NOT STUDIED)
EAGLE FORD GROUP
MIDWAY
NACATOCH
TAYLOR
KEECHI DOME
LEGEND:
GEOLOGIC UNITS THAT MAY HAVE GOOD WATER TRANSMITTING PROPERTIES.
GEOLOGIC UNITS THAT GENERALLY HAVE POOR WATER TRANSMITTING PROPERTIES.
CAPROCK
SALT
TOP OF LOGGED INTERVAL FOR GEOLOGIC INTERPRETATION.
FAULT, DASHED WHERE INFERRED
FORMATION CONTACT
INFERRED FORMATION CONTACT
APPROXIMATE WATER TABLE CONFIGURATION
APPROXIMATE BASE OF FRESH WATER
4000 0 4000 FEET
1000 0 1000 METERS
VERTICAL EXAGGERATION X4
GEOLOGY MODIFIED FROM TEXAS BUREAU OF ECONOMIC GEOLOGY, 1980
ANDRADE #1 FITZGERALD
HUMBLE #C-1 SAMPSON
MEADOWS #1 CONCORD
LA RUE #1 JERNIGAN
NAVARRO #4 GREENWOOD
NAVARRO #3 GREENWOOD
NAVARRO #2 GREENWOOD
NAVARRO #1 GREENWOOD
NAVARRO #1 BARRETT
PRODUCERS #5 BARRETT AND GREENWOOD
FARISH III #1 WAITS
OLSON #1 JORDAN
-3000
N
0 2 MILES
0 3 KILOMETERS
LINE OF SECTION

PREPARED LLL DATE 9/28/81
REVISED DJP DATE 11/17/81
REVISED DATE
APPROVED RSM DATE 9/28/81
T-1923-1

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

EAST TEXAS STUDY AREA
HYDROGEOLOGIC CROSS-SECTION THROUGH KEECHI DOME

JOB NO. MV9700 FIGURE 8-18

BEST DOCUMENT AVAILABLE

Drilling and aquifer testing, although planned for Keechi Salt Dome, were not initiated. At present, there is no evidence to suggest that the aquifer characteristics at this dome are different from those found regionally. However, the probability of generating more hydrologic data may permit specific characterization.

8.3.3.2.2 Ground-Water Flow Time Analysis - Following a report by Pacific Northwest Laboratories (1979), LETCo investigated estimated average ground-water flow times from various depths upward to the base of the fresh-water surface at Keechi Salt Dome (Law Engineering Testing Company, 1981). Graphical results of the analyses are shown in Figure 8-15. The analyses indicate that the estimated average ground-water flow times are long (hundreds of years per foot of flow path), and significant differences in these flow times among the candidate domes cannot be substantiated with the existing data.

8.3.3.3 Water Chemistry: The chemical composition of water in the vicinity of Keechi Salt Dome was investigated. Surface-water chemical data collected by USGS (Yost, written communication, 1980) have been studied and integrated with ground-water chemical data retrieved from TNRIS.

Results of field measurements at 13 surface-water sites in the vicinity of the dome indicate surface waters are acidic and low in total dissolved solids. Specific conductances range between 90 and 400 micromhos per centimeter. Reported pH values ranges between 4.2 and 7.3 standard units. The great range in pH may be significant.

Laboratory results for samples from four surface-water collection sites indicate surface water around the dome is nondescript, having similar concentrations for several dissolved constituents. Total dissolved-solids concentration ranges between 90 and 200 mg/l (90 and 200 ppm).

Ground-water quality of aquifers in the vicinity of Keechi Dome is similar to that encountered regionally. Generally, the water is a calcium bicarbonate or sodium bicarbonate type and is low in total dissolved solids.

8.3.3.4 Relationship of Surface Water to Ground Water: It is expected that base flows of streams over Keechi Dome will be the same or higher than base flows of streams in other parts of the study area. Formations outcropping over Keechi Salt Dome are predominantly sediments of the Claiborne and Wilcox Groups (Figure 7-17). The water-bearing and water-transmitting properties of these groups are high. Quantitative measurements of base flow of streams in the study area have not been made and no historical records exist.

8.3.3.5 Water and Aquifer Use: Ground-water withdrawals in Anderson County are moderate and they are predominantly from the Carrizo and Queen City Formations. Palestine, the largest city in the vicinity of Keechi Salt Dome, withdraws approximately 4 million l/day (1 million gal/day) from the Carrizo aquifer for municipal and industrial purposes. The remaining water pumped from the Carrizo aquifer is used in communities south of Keechi Salt Dome (Guyton and others, 1972). A cone of depression in the potentiometric surface of the Wilcox-Carrizo aquifer is centered around Palestine and locally affects the ground-water flow pattern (see Figure 8-6).

8.4 HYDROLOGIC CHARACTERIZATION SUMMARY OF THE EAST TEXAS STUDY AREA

The East Texas Study area is located in the Trinity River watershed. Oakwood Dome is located in the Upper Keechi Creek watershed. Keechi Dome is located in the Keechie Creek watershed.

Discharge occurs to major streams from formations incised by these streams. This ground-water discharge to streams is probably greatest in the northwestern part of the study area, decreasing to the south and east.

Surface water of suitable chemical quality is available for most uses. Water used from surface sources is generally for industrial and agricultural supplies. Use of surface-water supplies has shown a marked increase in the past 20 years, with ground-water withdrawal showing only a small increase in the study area.

Aquifers and confining layers in the study area were identified. Upper Cretaceous deposits capable of transmitting water are the sands of the Woodbine Group and possibly the Nacatoch Formation of the Navarro Group. All other Upper Cretaceous deposits are considered confining layers. Tertiary aquifers include the Wilcox Group and the Carrizo, Queen City, and Sparta Formations of the Claiborne Group. Quaternary alluvium and terrace deposits are also considered aquifers. The Midway Group, Reklaw, Weches, and Cook Mountain Formations of the Claiborne Group are considered confining layers.

The hydraulic properties of aquifers underlying the study area were determined only at Oakwood Salt Dome. Hydraulic conductivities of the formations tested are similar to those reported regionally but they tend to be in the low range.

Areas of recharge to aquifers were identified and directions of ground-water movement were determined. In general, recharge to the Upper Cretaceous deposits occurs northwest of the study area where these units are exposed at the surface and can be replenished by rainfall. This water flows south to southeast through the study area. Recharge to Tertiary and Quaternary deposits in the study area occurs directly from rainfall and leakage between aquifers. Water in these aquifers generally flows towards the Trinity River in a southeasterly direction.

The chemical character of the ground water changes with depth. Ground water in shallow surficial aquifers is mostly calcium bicarbonate water. Predominant ions in the water change from calcium bicarbonate to sodium bicarbonate to sodium chloride with depth. Depth to saline water is shallowest over the domes but it generally coincides with the base of the Wilcox Group. Depth to saline water is greatest in the eastern and southeastern portions of the study area.

[redacted]

Aquifers in the study area are used for water supply and brine waste disposal. Largest withdrawal of ground water is centered around Palestine, Texas. The Wilcox-Carrizo aquifer system is the largest source of ground water. Disposal wells are concentrated in southern and central Anderson County. Most disposal wells inject waste into the Woodbine Group.

Sufficient ground-water chemistry and hydrogeologic data are not available at this time to adequately characterize any local or dome-specific trends in aquifers in the study area.

Analyses were conducted at Oakwood and Keechi Domes to determine estimated average ground-water flow times from depth upward to the base of fresh water. A vertical upward flow path was assumed to fulfill minimum time as well as distance requirements. It was concluded, on the basis of data currently available, that average flow times were great (hundreds of years per foot of flow path length).

Areas that would be inundated by flooding of streams were delineated above the two candidate domes. Data needed for these studies were taken from U.S. Geological Survey 1:24,000-scale quadrangle maps. No field data were obtained. Maximum flooding at Oakwood Dome would inundate approximately 9 percent of the projected supradomal area at the -610-meter (-2,000-ft)-MSL salt dome contour. Maximum flooding of streams overlying Keechi Salt Dome would inundate approximately 17 percent of the projected supradomal area at the -610-meter (-2,000-ft)-MSL salt dome contour.

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REVIEW COMMENTS TO DRAFT REPORT WITH REPLIES

262

Comments on the First Draft of the East Texas Area Characterization Report by Texas Bureau of Economic Geology, May 13, 1980, with Replies

GEOLOGIC CHARACTERIZATION OF THE EAST TEXAS BASIN STUDY AREA

1. Page 6-1. What is the purpose of Section 6.0?

This section has been moved to Section 6.4 SUMMARY OF THE EAST TEXAS STUDY AREA, Final Report Texas ACR.

2. Page 6-1. Delete the word ridges from the sentence which reads: movement of the Louann Salt, as a result of sedimentary loading, is believed responsible for controlling the location of the structurally high ridges and intervening subbasins.

Structurally high ridges has been changed to structural highs in Section 6.4 SUMMARY OF THE EAST TEXAS STUDY AREA, Final Report Texas ACR.

3. Page 6-3. TBEG suggests that oil production may be expected to decline near specific domes.

The sentence reads: Exploration and production of these resources is expected to continue with gas and lignite production increasing, whereas oil production is expected to decline. This paragraph has been moved to Section 6.4 SUMMARY OF THE EAST TEXAS STUDY AREA, Final Report Texas ACR. The sentence has been changed in part to read: "...whereas oil production is expected to decline at the fields near specific domes."

DESCRIPTION OF THE STUDY AREA

4. Page 6-3. Add the word originally to the last sentence of the first paragraph which reads: The area, lying entirely within the Gulf Coastal Plain, is an oval enclosing the three salt domes selected for study --- Keechi, Oakwood, Palestine.

In Section 6.1 DESCRIPTION OF THE STUDY AREA, Final Report Texas ACR, the word originally has been incorporated: The sentence reads in part "... the three domes originally selected ...."

STRATIGRAPHY OF THE STUDY AREA

5. Page 6-16. TBEG has changed cycles to sequences.

"Cycles" has been changed to "sequences" in Section 6.2.2 STRATIGRAPHY, Final Report Texas ACR.

6. Page 6-16. TBEG has also changed total depth of sedimentation in their annual report paper from 25,000 feet to 19,000 feet.

The total depth of sedimentation has been changed from 25,000' to 19,000' in Section 6.2.2 STRATIGRAPHY, Final Report Texas ACR.

7. Page 6-17. TBEG has changed "Paleogene": to "Tertiary clastics".

In Section 6.2.2 STRATIGRAPHY, Final Report Texas ACR the six depositional cycles have been changed so that the use of stratigraphic nomenclature is consistent.

8. Page 6-17. TBEG questions the paragraph which discusses the depositional history of the study area.

This paragraph has been incorporated into Section 6.2.4 GEOLOGICAL HISTORY, Final Report Texas ACR.

Tertiary System (Paleocene and Eocene)

9. Page 6-28. TBEG has changed cycles to sequences.

This has been incorporated in Section 6.2.2.4 Tertiary, Final Report Texas ACR.

Quaternary

10. Page 6-30. TBEG does not understand the sentence which reads: The older Pleistocene sediments are generally found at higher elevations than the younger Pleistocene and Recent sediments.

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This sentence has been deleted from Section 6.2.2.5 Quaternary, Final Report Texas ACR.

STRUCTURE OF THE STUDY AREA

11. Page 6-31. TBEG questions the validity of our definition of the East Texas Basin.

The definition of the East Texas Basin has been modified in Section 6.2.3 STRUCTURE, Final Report Texas ACR.

12. Page 6-31. Our estimate of the size of the East Texas Salt Dome Basin seems too small.

This sentence has been deleted from the Final Report.

13. Page 6-31. TBEG indicates that the salt dome basin contains variable thickness of Louann salt and that in some places it is zero.

This is in response to the portion of the sentence which reads: It contains a great thickness of Louann Salt ... In the Final Report Texas ACR, Section 6.2.3 STRUCTURE, the sentence has been changed to read: "... with a variable thickness of Louann Salt."

14. Page 6-32. What is the definition of rim syncline?

In Section 6.2.3.1 Salt Structures, Final Report Texas ACR, rim syncline is defined. A more detailed definition is in the Glossary.

Subsidence and Dome-Related Warping

15. Page 6-34. How do you separate salt mobilization from basin subsidence?

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In the Final Report Texas ACR, Section 6.2.4 GEOLOGICAL HISTORY, the interpretation of the role that isostatic adjustment played relative to subsidence has been deleted. Salt mobilization has not been separated from basin subsidence. Structural contour maps were utilized (Figures 6-26 through 6-32) to demonstrate the relationship between sedimentary deposition, basin subsidence and salt movement.

Salt Movement

16. Page 6-36. There is no reference to Figure 6.2.28.

The paragraph pertains to movement of the salt and associated faulting. In the Final Report Texas ACR, Section 6.2.3.2.1 Supradomal and Other Local Faulting, Figure 6-19 - Major Faults Trends (on Cretaceous horizons) has been referenced.

17. Page 6-37. Move Butler Dome from Burial Stage to Truncation Stage.

In the Final Report Texas ACR, Section 6.2.4 GEOLOGICAL HISTORY, Butler Dome represents the truncation stage based on salt dome growth rate models. A detailed discussion of salt dome growth rates and growth stages can be found in the second draft Area Characterization, Vol. I, Introduction, Background and Summary, Section 2.2 SALT DOME GROWTH RATE STUDIES.

Keechi Dome

18. Page 6-39. Cross reference this section to later sections.

This section describes the location of the dome, physiography of the dome, the depth to salt and the shape of the dome. In the Final Report, Section 6.2.3.1 Salt Structures, the information relative to the physiography, the depth to salt and geometry has been retained. Information about the location of the dome has been transferred to Section 7.2 KEECHI DOME.

Palestine Dome

19. Page 6-40. Where is the figure reference for Palestine Dome?

In the Final Report, Section 6.2.3.1 Salt Structures, Figure 6-7 - Geological Map of East Texas Study has been referenced.

20. Page 6-40. Where is the figure reference for Butler Dome?

Figure 6-9 (Salt Masses and Major Salt Anticlinal Trends) has been referenced in the Final Report, Section 6.2.3.1 Salt Structures.

21. Page 6-41. TBEG surface mapping (Palestine sheet) indicates Reklaw faulted against Cretaceous. This suggests dome movement as late as Claibornian time. TBEG can see no evidence of burial by overlying sediments (see p. 6-37).

The sentence in question reads: The shape of the dome and its relationship to the surrounding sediments is unclear, therefore it is questionable if Butler has reached a mature stage of development before stabilizing. In the Final Report Texas ACR, Butler Dome has been moved from the Burial Stage of dome development to the Truncation Stage. See Final Report, Section 6.2.4, GEOLOGICAL HISTORY.

Bethel Dome

22. Page 6-41. The dome is in the wrong location.

In the Final Report, Section 6.2.3.1 Salt Structures, reference to the location of the dome has been deleted.

23. Page 6-41. The Wilcox Group is not shown on the TBEG Palestine sheet.

This comment refers to the sentence that reads: The oldest unit exposed at the surface is the Wilcox Group, and these sediments also lie in contact with the salt. The sentence has been deleted from the Final Report.

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24. Page 6-41. The sentence reads: In the subsurface sediments of Upper Cretaceous and younger thin as they dip gently away from the dome, whereas older sediments thicken as they dip away from the dome. TBEG suggests we change "dip gently away" to "toward." In the last part of the sentence change "away" to "toward."

This sentence has been deleted from the Final Report Texas ACR.

25. Figure 7.3-10 (FIRST DRAFT). The surface geologic map of Keechi Dome does not show any Cretaceous at the surface over the dome. Ebanks' thesis map shows Cretaceous at the surface.

In the Final Report Texas ACR, the Cretaceous outcrop has been added.

Regional Tectonics and Seismicity

26. Page 6-51. TBEG suggests referencing the Geologic Circular 80-1 Quaternary Faulting in E. Texas instead of referencing the GSA abstract that was given in 1979.

The reference change has been addressed in Section 6.2.5.2 Regional Tectonics and Seismicity, of the Final Report Texas ACR and the appropriate changes have been made in the List of References Cited.

27. Page 6-52. This statement is incorrect --- see BEG GC-80-1, p. 5 and 6: that at the three small faults "the Quaternary unit displays cumulative throws of 53 cm (21 in.), 22 cm (9 in.), and 66 cm (26 in.)."

In the Final Report, Section 6.2.3.2.2 Mt. Enterprise Fault Zone, item #1 concerning the exposure along the Trinity River, has been changed to reflect the cumulative displacements as stated by TBEG in their report BEG GC-80-1 Quaternary Faulting in East Texas.

28. TBEG found no list of references in the First Draft.

In the Final Report Texas ACR, List of References Cited appear at the end of each Chapter.

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